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THE STATUS OF WETLANDS SCIENCE

HEARING

BEFORE THE

SUBCOMMITTEE ON
ENVIRONMENTAL PROTECTION

OF THE

COMMITTEE ON
ENVIRONMENT AND PUBLIC WORKS
UNITED STATES SENATE

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THE STATUS OF WETLANDS SCIENCE

TUESDAY, APRIL 9, 1991

U.S. SENATE,
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS,
SUBCOMMITTEE ON ENVIRONMENTAL PROTECTION,
Washington, DC.

The subcommittee met, pursuant to notice, at 10:12 a.m. in room 406, Dirksen Senate Office Building, Hon. Max Baucus [chairman of the subcommittee] presiding.

Present: Senators Baucus, Chafee, and Durenberger.

OPENING STATEMENT OF HON. MAX BAUCUS, U.S. SENATOR FROM THE STATE OF MONTANA

Senator BAUCUS. The hearing will come to order.

I would first like to state that Senator Chafee, the ranking member of the subcommittee and also the full committee is presently testifying at another hearing and he will be with us shortly. He regrets that he is unable to be here at the beginning of the hearing.

The Subcommittee on Environmental Protection convenes today to review the state of the science regarding several wetland technical issues which will be relevant to our efforts to reauthorize the Clean Water Act in the months ahead. Specifically, our purpose here this morning is to explore the extent of scientific knowledge in four areas.

First, we will want to find out what we know about the functions and values of wetlands, particularly those that are only seasonally wet. Second, we will look at our present capabilities and tools to assess wetland functions. Third, we will examine our present capabilities to restore or create wetlands. Finally, we will review the success to date of wetland restoration and creation efforts.

Wetlands are our most important aquatic environments. They are essential to achieving the Clean Water Act's goal of restoring and maintaining the chemical, physical, and biological integrity of the Nation's waters.

Wetlands help maintain and improve water quality by removing and retaining nutrients, processing wastes, and reducing sediment. They temporarily store floodwaters, thereby reducing downstream flood peaks and protecting property owners from flood damage. By recharging groundwater, wetlands help maintain water table levels needed to provide irrigation and drinking water supplies and prevent loss of soil moisture.

Wetlands sustain most of the Nation's fisheries. Nearly all recreationally important fresh water fish are dependent upon wet-

lands and associated near-shore waters for spawning sites, nursery areas, and sources of food. Wetlands are especially important as breeding grounds, over-wintering areas, and feeding sites for water fowl and many other migratory birds. These aquatic habitats also support over one-third of all threatened and endangered species in the United States.

Each year in my State of Montana, nearly 400,000 people spend over $160 million to go fishing. Almost 30,000 spend millions of dollars more hunting water fowl, and nearly three Montanans out of every five enjoy watching and photographing water fowl and other wildlife species.

Nationwide, wetlands sustain the fisheries and wildlife that generate annual expenditures in excess of $40 billion. Unfortunately, the food, recreation, and jobs provided by wetlands are in jeopardy. According to an 1982 report by the U.S. Fish and Wildlife Service, wetland losses averaged 458,000 per year for the 1950's to the 1970's. Over 95 percent of the losses were inland, fresh water wetlands resulting in a new loss of 11 million acres, an area twice the size of the State of New Jersey.

More than 50 percent of the wetlands in the lower 48 States that existed in the late 18th Century have been lost. My State of Montana has fared better than the National average, but still has lost more than a quarter of its original wetlands.

The Burgess Sea Resources Act of 1986 directed the U.S. Fish and Wildlife Service to update its 1982 report on the status and trends of the Nation's wetlands by September of last year. We had hoped that this report, covering the period from the mid-1970's to the mid-1980's would be available for this hearing. It should illustrate the effects of wetlands lost that have resulted from changing land use practices, population movement to the coasts, and Federal, State, and local wetland protection measures during that decade.

Regrettably, this revised report is still undergoing review. We do, however, have six of the Nation's foremost experts in wetland functions, assessment, and restoration and creation with us today. I want to welcome them and thank them for traveling to Washington to assist the subcommittee.

Our first panel will consist of Dr. Daniel Hubbard, Department of Wildlife and Fisheries Sciences at South Dakota State University; Dr. Mark Brinson, Biology Department of East Carolina University in Greenville, North Carolina; and Dr. Joseph Larson, Director of the Environmental Institute, the University of Massachusetts, Amherst, Massachusetts.

Gentleman, why don't you three come up to the witness table and begin? We have a five minute rule here. At the beginning of your testimony, a green light comes on. When there is about one minute left, the amber light, and when your time is up, the red light will be on. I will enforce that five minute rule.

I might also indicate that present in the hearing this morning are several students from the Montana School for the Deaf. They are here observing the hearing. It is a great experience for them. They have come all the way from Montana to participate, and they are fully participating in the hearing. I am very happy and honored to have them here present with us.

Dr. Hubbard, why don't you begin?

STATEMENT OF DANIEL W. HUBBARD, DEPARTMENT OF WILDLIFE AND FISHERIES SCIENCE, SOUTH DAKOTA STATE UNIVERSITY

Mr. HUBBARD. Thank you, Mr. Chairman. It's an honor to be here. Thank you for inviting me here to speak before the subcommittee.

Most of my remarks today will specifically address the wetlands in what we call the Prairie Pothole Region of North America. They are in an area in the northern prairies from Iowa up through the Dakotas, parts of Minnesota and Montana, and then up in the prairie provinces of Canada.

Some of the things I will say today may not necessarily apply to wetlands systems in other parts of the country. They are different in different areas. I was asked by the subcommittee to specifically address the seasonal type of wetlands.

In the prairie areas, we have several different kinds of "seasonal wetlands," if you will. In terms of one classification system that we use frequently up there, we can classify wetlands by essentially four different water regimes, at least most commonly. There are others that are less common.

One is ephemeral, which are only wet for just a few days immediately in the spring, usually when the ground is still frozen. That particular wetland classification usually would not be classified as wetland under the Federal jurisdictional manual, and I really will not address those today.

The other three types are termed temporary wetlands, which are usually wet in an average year—average is an abstract term; I'll get to that in a minute—for perhaps a week to a month; seasonal wetlands, which are wet from the order of a month or so to about half the growing season, but usually never throughout the whole growing season; and then semi-permanent wetlands, which are typically wet through most of the growing season in the average year.

The term average, as you are probably very well aware, Mr. Baucus, being from a prairie State, is purely that. It is abstract. We are a land of extremes. One year we have more than "average rainfall" and the next year we have way less than average. An actual year where we get an average amount of rainfall is very rare indeed. It is purely a mathematical expression.

Another thing to keep in mind is that runoff is extremely important, not necessarily the total amount of precipitation in any given year. This makes correlating the number of wet ponds on the prairies with annual precipitation very difficult to do. We can have an average year of "rainfall" yet not have a lot of wetlands wet, because they are primarily dependent on runoff and runoff depends on the intensity of a certain type of runoff event, like snow melt in the spring or intensity of summer thunderstorms.

In a nutshell, the climate of the prairies, being very extreme, means we can have several years in a row where these temporaries and seasonals may be wet every year for several years. We can have several years in a row where the temporary and seasonal wetlands may be dry. Depending on your frame of reference and what set of years you pick to decide what an average condition for a par-

ticular site is can influence what the decision one might make on whether or not it is a wetland. I am speaking in terms of, say, some of the landowners perspectives, where they may debate on whether or not this wet spot in the field is in fact a wetland.

Now these small temporary and seasonal wetlands are typically less than five acres and probably the majority of them are under a couple acres in size. In any given year, at least 50 percent of them are cultivated and planted with crops. This does not really lessen any of their functional values for most types of functions.

These seasonal wetlands are groundwater recharge sites on the prairie. Semi-permanent wetlands are typically groundwater discharge sites or what we call groundwater flow-through sites. That is that sometimes in one part of the basin, groundwater may be seeping into them and in another part of the same wetlands, groundwater may be seeping into the groundwater.

During years of extreme drought, when the water tables are low, even the semi-permanent wetlands can function as groundwater recharge sites when the bottoms of the sloughs are above the water table. These seasonal and temporary wetlands increase the carrying capacity of any given section of land for water fowl protection. They also store a very large amount of runoff, which when drained, can aggravate flooding problems lower in the watershed.

I see I am starting to run out of time here. I can get long-winded.

Senator BAUCUS. I'll give you a couple more minutes.

Mr. HUBBARD. OK.

Each individual wetland itself may not have a great amount of functional value in and of itself, but when combined with the hundreds of thousands of depressions out there, en masse, they have great value, especially in terms of waterfowl production, in terms of floodwater storage, and in terms of groundwater recharge. The groundwater recharge out there on the prairies is very important, especially in the Dakotas and Montana where high water tables are known to contribute soil moisture to the soil zone above it. If most of those are drained, at least in theory, we can drop the water table a few feet and could possibly affect agriculture in the prairies by decreasing a significant source of soil moisture recharge.

I think I will let it go at that. My more detailed comments are in my written statement.

Senator BAUCUS. Do you have another point you want to make before we pass on to others?

Mr. HUBBARD. No, sir. I think I can wait until the questions.

Senator BAUCUS. OK.

Dr. Brinson.

STATEMENT OF MARK M. BRINSON, BIOLOGY DEPARTMENT, EAST CAROLINA UNIVERSITY

Mr. BRINSON. Thank you, Mr. Chairman.

The information that we have available for assessing the functions of wetlands has grown tremendously in the last 20 years or so. This should not be construed to mean that we can answer all questions about them, however. I feel confident though that we can qualitatively assess their ecological functions and infer what values they have that are of benefit to society.

The resources we are talking about are not pristine sites that have never been altered or subjected to damaging impacts. Some are surrounded by cities; some by intensive agriculture. This national infrastructure of wetlands is working to capacity in many cases to keep water as clean as possible and at the same time to accommodate wildlife and to perform hydrologic functions.

For each acre of wetland that is removed from this network, either we lose the functions completely or the burden is shifted to other wetlands nearby. Our wetlands, in many cases, are overworked and some of our federally owned and managed wetlands are heavily impacted.

I have been asked to address the functions of wetlands in the Southeastern US, especially those that are non-tidal, that have fresh water and are dominated by woody vegetation. In the interest of time, I will mention only two types.

The first is the headwater stream wetlands or headwater stream bottomlands. These are intermittently flooded and are found on low order streams. The others are the pocosin peatlands. These are peat bogs that occupy interstream divides and depressions including the so-called Carolina bays.

The reason I treat these two separately is because they are so different that it is not good judgment to compare them with each other. Incidentally, this is one of the reasons that ranking of wetlands is not desirable, a matter to which I will return.

First, the headwater stream bottomlands. These wetlands are among the most effective anywhere for reducing nonpoint sources of nutrients and sediments from reaching streams and rivers. This derives from the fact that the length of headwater streams exceeds that of other stream sizes and the fact that they interface extensively with uplands. Their capacity to trap sediments and nutrients generated from agricultural activities, for example, has been demonstrated conclusively in Maryland, North Carolina, Georgia, and elsewhere.

What are the consequences of altering these wetlands such as filling or draining them? Not only do the normal processes of sediment trapping and pollutant filtering cease, but the wetland becomes a liability rather than an attribute. The function reverses from one of removing pollutants to one that releases material to downstream ecosystems, contributing to eutrophication. The implications for water quality are obvious.

Pocosin peatlands that occupy interstream divides are at the highest elevations within the coastal plain drainages. Their landscape position is above headwater streams in most cases. They have been accumulating large amounts of organic matter as peat for the past 5,000 to 10,000 years. The origin of this carbon is from carbon dioxide in the atmosphere.

So what are the consequences of draining these pocosins? Installation of ditches to improve drainage exposes the organic soils to additional oxygen and subjects the land to organic matter oxidation and subsidence, including the very rapid losses during peat fires. The switch from a sink for carbon dioxide from the atmosphere to a source is again a reversal in function that occurs at a much accelerated rate relative to the original function. The significance for global climate changes is apparent. Pocosins in the Southeast have

their counterparts in the old-growth forests of the Pacific Northwest and the rain forests of the tropics in terms of the contribution to atmospheric carbon dioxide when they are disturbed.

Finally, just a few words about assessment of wetlands. It is my experience that most methods for assessing wetlands are fundamentally flawed because they try to compare functionally different wetlands. It is equivalent to comparing highway vehicles and ranking them without any particular purpose in mind.

Which is better or ranks higher, a Chevrolet Corvette or a Mack truck? Which is better, a headwater floodplain bottomland or a pocosin peatland?

Wetlands are enough different from one another that this is not a trivial issue. Beyond the fact that assessment techniques often don't get the science right, there are other problems with assessment, inadequately trained people doing the assessment and the fact that agencies are frequently understaffed that have responsibility and oversight for enforcement. These latter two issues get a bit into the policy area. I think we first need to get our science right and then the policy people can take it from there.

Thank you.

Senator BAUCUS. Thank you, Dr. Brinson.

Our final witness for this panel is Dr. Larson.

STATEMENT OF JOSEPH S. LARSON, DIRECTOR, THE ENVIRONMENTAL INSTITUTE, UNIVERSITY OF MASSACHUSETTS

Mr. LARSON. Thank you, Mr. Chairman. I've been asked to address saturated wetlands, wetlands that are infrequently inundated on the surface in the Northeastern United States.

In the Northeast, these are largely forested swamps, forested floodplains, wet meadows, bogs, and vernal pools. As in other parts of the country, we have lost perhaps half of our wetlands. Today, forested wetlands in the Northeast alone comprise well over half of the wetlands remaining in the Northeast. When you see a tree growing in a wetland in New England, you know that that area is not inundated for any longer than 30 days during the growing season.

For wildlife habitat, these wetlands have an extremely important function. They are highly significant for migratory songbird breeding habitat. It is not just the ducks, geese, and swans that we have a responsibility for under the Migratory Bird Treaty Act or under the Ramsar Convention on Wetlands of International Importance. It is other birds as well.

As many as 46 different species of birds breed in the forested wetlands of West-central Massachusetts. Indeed, four species of migratory waterfowl use wetlands heavily in the Northeast, including the black duck, mallard, wood duck, and hooded merganser.

The vernal pools—these are the small pools that invariably dry up at some time during the summertime and often occur in forested wetlands in our part of the country—are an essential breeding habitat for amphibians. Without vernal pools, the amphibian population would not exist. They need areas to breed that are free from predatory fish populations. Many mammal species are also common in forested wetlands in the Northeast.

Bogs are extremely unique, highly stressed, and very specialized communities. As a result, they support very unique plant and animal communities, and from a scientific research and genetic gene pool view, these wetlands are extremely critical.

Often overlooked, because there is so much information on wildlife use of wetlands, is the importance for wetlands with regard to flood control and surface water quality. In my State, which has regulated wetlands longer than any other governmental jurisdiction in the world, we first became concerned about fresh water wetlands because of their role in floodwater control.

Large forested wetlands and wet) meadows on floodplains along the middle reaches of river systems in the Northeast play an important role in detaining floodwaters and maintaining water quality. During floods, these wetlands are areas where sediment settles out. Of course, sediment is the substrate for attachment of pollutants like bacteria, heavy metals, and excess nutrients.

There are important groundwater implications with regard to these kinds of wetlands in the Northeast. Most of the saturated wetlands in the Northeast are discharge sites. This means that they are working as large diffuse springs, and in some cases, as sources for intermittent and small permanent streams. In Massachusetts alone, 60 municipalities draw their drinking water from wells drilled in or near large forested wetlands.

There is another side to this coin. That is the risks and costs of altering the wetlands for some other purpose, particularly for agriculture and particularly for residential and second home use. This kind of limitation is not a secret. It doesn't take an advanced science degree to learn that you don't try to grow row crops or you shouldn't expect to get good quality timber production and you shouldn't be building homes on these kinds of soil sites. You can find this information very adequately documented in the county soil surveys of the U.S. Department of Agriculture and in the records of the health boards of many New England municipalities.

These soils, which are generally termed hydric soils, impose especially important costs and risks that, if the wetland is improperly used, particularly for municipal development, causes a major financial cost on the local community. The reason for this is that these sites are wet by rise in groundwater to or near the surface at some time during the year. This saturation causes septic systems to fail and causes fresh water infiltration into municipal sewer systems.

A great deal of the Northea, unlike the newspapers would lead you to believe, is not asphalt from the Atlantic Coast to the central part of New York. Our own State is perhaps 70 percent forested. A great number of the homes in the Northeast are dependent upon obtaining water and disposing of their sewage on site. You have a private well and you have a septic system on the same house lot.

If you build on these hydric soils—and these are the soils that underlie these saturated wetlands—that septic system is going to fail and going to pose a health problem to your well and to your neighbor's well. Having been former chairman of a local board of health in a small forested community, I have seen too many instances where improper development on these saturated soils have led to a public health problem.

I would like to say something about ranking and the use and misuse of ranking. Many of us in wetlands science have been involved in attempting to develop procedures to assess whether wetlands perform a certain function or not. These tools have been developed primarily for planning purposes. It concerns many of us to see them improperly used in terms of regulatory purposes.

The most well known system is the Wetland Evaluation Technique or WET system that was developed first by the Federal Highway Administration and now is supported by the Corps of Engineers. Unfortunately, that system, although it is very useful from a planning point of view to make an initial cut to determine where problems are likely to occur, is being misused as a regulatory tool. It's being misused to judge whether a replacement wetland will function as an adequate substitute for a natural wetland.

Lastly, wetland inventory maps, I suspect, are being misused in a regulatory function. The National Wetland Inventory or NWI maps that have been produced for large parts of the country are very useful inventory and planning tools. However, we are very concerned about proposals to use these maps and the nomenclature on them to set aside certain groups of wetlands that are supposedly of low value.

These maps were never designed to equate with functions of wetlands. It is just as improper to use them for that function as it is to use them for delineating wetland boundaries. Thank you very much.

Senator BAUCUS. Thank you very much, gentlemen.

First, I would like to ask the panel generally—you've touched on this already in your testimony, but I think it is important to develop it for the record—what are some of the values of wetlands? We have fisheries and waterfowl that are certainly dependent upon wetlands in America. You've touched upon sediment collection, filtration, groundwater recharge, et cetera, but if you could just outline the basic values of wetlands in America in laymen's terms, that would be helpful.

Anyone may begin.

Mr. BRINSON. I'll take a cut at it.

The three basic values are habitat value for waterfowl, wildlife, fish, fisheries, and so forth; the hydrologic function and value in terms of storing storm waters, eliminating or reducing flooding; and third is the water quality issue, the extent to which they can improve water quality. In terms of putting dollar signs on those, that is very difficult. It has been done in a number of cases, but there is no agreement as to how it should be done.

Senator BAUCUS. Would the other two agree that those are the basic values—habitat, hydrologic, and environmental? Is that a good, fair characterization?

Mr. LARSON. Yes, sir, but I would urge you to look at the other side of the coin. That is the public costs if those functions are no longer provided, the cost of replacing the flood control retention and detention.

Senator BAUCUS. OK.

Let's turn a bit to the science. In which areas do most scientists have the greatest comfort, the greatest degree of certainty of assessing those values, compared with others? Do we have a better

idea of the degree to which fisheries are destroyed when wetlands are destroyed and, say, waterfowl habitat destroyed when certain wetlands are destroyed compared with hydrologic and environmental? I am just trying to get a sense of where we know more and where we know less.

Mr. BRINSON. Certainly in terms of the number of studies and information available, the wildlife and fish functions are highest and best understood. After that, I would put water quality and, finally, hydrology is probably the least understood and the least well documented. It's a difficult science.

Most people studying wetlands are biologists and there has not been that much attention given to the hydrologic functions.

Senator BAUCUS. Would both of you agree?

Mr. LARSON. I would qualify it and say, yes, wildlife, but we are really talking about waterfowl. There are hundreds of other species that are dependent upon wetlands as habitat for which we have very little information, very little basic information.

Senator BAUCUS. For example?

Mr. LARSON. Our songbirds. The study I referred to with 47 species breeding in large wetlands in Massachusetts is probably the only study on songbird habitat in forested wetlands in the Northeast.

Senator BAUCUS. Might that be true in other parts of the country, or do you know? That is songbird dependence on wetlands.

Mr. LARSON. Yes, I would say that it would be true largely in other parts of the country.

Senator BAUCUS. Besides songbirds, does any other wildlife come to mind?

Mr. LARSON. Amphibians and reptiles. I have a study that has just started that is the first attempt to develop assessment for amphibians and reptiles.

Senator BAUCUS. What are some—you've all gone into this, but it would help to draw this out in more detail—of the environmental values of wetlands?

Dr. Brinson, you talked about upland, the headwater wetlands containing sediment and if the wetland is destroyed, it goes downstream, et cetera.

Mr. BRINSON. Right.

Senator BAUCUS. Could all three of you touch a little more on the environmental value of wetlands and examples that come to mind?

Mr. LARSON. Well, the best example in terms of the role of wetlands in flood control, and carrying it right on to a dollar value, was work done by the Army Corps of Engineers in Charles River, Massachusetts, where the Corps came to the decision that it was more cost-effective to restrict the use of 8,000 acres of wetlands, buy some of it, for its Natural Valley storage than to construct flood control structures downstream to protect the suburbs around Boston.

The flood control function, I think generally, though it has not been as well documented in terms of dollars, is recognized as one of the most important public safety issues with respect to wetlands.

Senator BAUCUS. So flood control is one—what else?

Mr. HUBBARD. In our region of the country, most values, if we're talking about an economic valuation of the functions of wetlands,

are not known. The functions, especially hydrological functions, have just recently been elucidated, so it is very difficult to put a real true value in terms of that.

Senator BAUCUS. When you say they are not well known, what comes to mind? What economic values do you think might be there if we knew them better?

Mr. HUBBARD. One is in terms of the hydrological balance, if you will, of the drought-prone prairies. There is only one watershed in Central North Dakota that has been hydrologically monitored by the USGS for a significant period of time. It is based on those studies that we know that these prairie potholes, no matter how small, are windows to the water table.

The agronomists have yet to take it a step further to say: OK, what value to agriculture is maintaining high water tables by maintaining these wetlands in their intact condition? We could be talking two or three bushels per acre per year in terms of having a water table that is, say, 10 feet below the soil surface versus one that is 15 or 20 feet below the soil surface in terms of this recharge of soil moisture from the surface of the water table upward over the course of the wintertime.

It is a function that we know exists. Soil scientists are aware that it exists, but we do not have a good handle on how many bushels of wheat in North Dakota or Montana that we're talking about.

Senator BAUCUS. Has the water table lowered in the Northern Great Plains?

Mr. HUBBARD. In some areas it has; in some areas it has raised. It depends where you are. Unfortunately, most of the wetlands in the Prairie Pothole Region that we are talking about are situated in glacial till areas. These are very high enclaves.

Most municipalities get their water from groundwater in low stream valleys where the glacial deposits are out-washed. They are the recipients of the drainage from the higher levels in the till areas.

The USGS and most State geological surveys to not have monitoring wells located in the till—only in those that are used in municipal sources of water. Most on-farm wells are drilled to little buried sand lenses in the till itself and do not have any type of monitoring system.

It is tough. I went through to look through the State and Federal records in terms of long-term groundwater level monitoring, and it almost seems contradictory, but in some cases, the groundwater levels have been rising. That is because they are located at the lower elevations in the out- wash areas which receive the drainage from the higher elevation areas where the wetlands are being destroyed, if you see what I mean.

Senator BAUCUS. Some conclude that seasonal wetlands, because they are seasonal, are less important than others. What is your response to that?

Mr. HUBBARD. My response to that is that in our area, they are the ones that are the recharge sites constantly to the groundwater in the glacial till. They increase the carrying capacity for waterfowl, for instance, from the earliest they started taking records about 50 years ago through the early 1980's. There was a good correlation between breeding waterfowl populations and the number

of "wet ponds" in the prairies. Now the number varies from year to year depending on drought, but the total number has gradually taken a decline and so has the waterfowl population along with it.

That's about as much as we can quantify it. I suppose I could say that when we get to the point where we have zero wetlands, we will have zero ducks.

Since then, the two lines have kind of separated a little bit because of many other factors, low recruitment being one in terms of waterfowl populations.

Senator BAUCUS. I see Senator Durenberger is here, a very valuable member of our subcommittee.

Senator, do you have any statement or questions?

OPENING STATEMENT OF HON. DAVE DURENBERGER, U.S. SENATOR FROM THE STATE OF MINNESOTA

Senator DURENBERGER. If I may, Mr. Chairman, yes.

As you know, Mr. Chairman, you and I are both supposed to be in the Finance Committee dealing with universal access to health care and that sort of thing, and it's a compliment to you that you are here. It is a bigger compliment that you called a hearing on a subject that does not pull all the rest of the members of this committee but is incredibly essential do deal with. I really do compliment you for calling this hearing and I compliment you on the witnesses.

I read Dr. Hubbard's statement twice because it was about prairie potholes, which is where I come from. I think I know a lot more than I did. I am not sure that I understand it all, so I am really very, very pleased that the three of you and all the other witnesses have taken the time to be here.

This committee, as the chairman knows, will begin work on the clean water bill fairly soon. The chairman of the subcommittee and the ranking member of the subcommittee have not determined yet how best to handle the wetlands issue and there is a little reluctance to get into it, given all the controversy we find back home.

We had hoped that science would solve all of the controversy, but I doubt if it's going to. There is a little reluctance on people's part to involve ourselves in section 404 and the wetlands when we get to the clean water bill.

I would like to just take a minute, Mr. Chairman, and suggest with the help of these people that we really ought to consider dealing with the issue of wetlands as we do clean water. The first, as we should know by now with our experiences at home, is that section 404 does not do a very good job in protecting wetlands. Something like 87 percent of the loss we have is due to drainage, not to dredge and fill.

Now and then a valuable habitat is at stake under section 404 and the Corps or the EPA, maybe on the recommendation of Fish and Wildlife or some State agency, steps in to protect the natural resource from development and uses section 404 to do it, but most of the wetlands actions in this country happen outside the jurisdiction of the Clean Water Act. Section 404 is certainly nothing like a comprehensive program to protect wetlands and prevent loss.

My second thought is that 404 makes property owners who experience it firsthand really mad. They often see government in whatever form confused, scapegoating, and at cross purposes. The 404 horror stories abound, and I trust we are going to hear our share of them over the next few months.

So I say that when so many people are stressed out about a Federal program, it is probably time to take a look at it. Maybe it is also time for some reform as appropriate.

There are some important values reflected in the current 404 program, the definition of the resource, the requirement for mitigation, and we should not sacrifice those. But there are equally important objectives which we are not able to realize working with the current program.

For what it's worth, Mr. Chairman, I believe that the time for 404 amendment is now in this Congress and on this clean water bill.

The testimony of the witnesses here today is instructive in two areas: one is classification, and the other one is mitigation. I did read the testimony and I read it to urge caution on both counts, mitigation and classification.

I want to compliment whichever person on the staff put this little paper together, because it is terrific and it's short, and it says at the top of page 4 in at least partial response to your last question, Mr. Chairman, "The value of a wetland is a subjective determination of the significance that society places upon the function that it performs." I mean that is a wonderful statement.

We are doing the same thing downstairs in the Finance Committee, talking about universal access to health care. We're talking about values and we haven't figured out how to assess the value society puts on these things because we have made too many assumptions over 200 years and I think we have too much to catch up with. So I want to compliment whoever did that.

Senator BAUCUS. That's the wonderful Environment and Public Works Committee staff.

Senator DURENBERGER. I made that assumption, but I didn't know who specifically, so if it's the whole staff, compliments to the staff, and I will quickly wind this up, Mr. Chairman.

I read the testimony to urge caution on these counts because we don't fully understand the functions in this statement that wetlands perform, including the biological value of seasonal or temporary wetlands. It seems to me that a classification scheme that writes off presumably low value areas may be premature.

I am from a State that is starting to enact some legislation this year in that classification scheme. Gosh, after reading your papers I wish I could stay and listen to all the other testimony but I've got to get back to the Finance Committee. It just seems to me that running off on the classification thing very quickly and putting that into law is premature.

On the mitigation side, the testimony says to me that wetlands are difficult to create and that wetlands qualifying as replacement acreage in a mitigation program must be very carefully constructed and very carefully maintained to assure that the functions expected can be met over the long run. I really did not see any inconsistency in any of the statements that I read on those points.

To me, Mr. Chairman, in a generational sense or a cultural sense or a values sense, those are very, very important points. I thank you again and I thank our witnesses for the testimony.

Senator BAUCUS. Thank you very much, Senator. I appreciate the remarks and your help.

Dr. Brinson, could you comment a little more on the importance of headwater streams from the point of protecting nonpoint source pollution? As you know, we are going to revise the Clean Water Act this year, and one of the biggest problems we have is nonpoint source pollution.

Mr. BRINSON. Right.

Senator BAUCUS. In your testimony, you indicated that headwaters wetlands protection can play a very valuable role in addressing nonpoint source pollution. Could you expand on that a little more, please, maybe focusing on whether we are talking about permanent standing water or seasonal wetlands?

Mr. BRINSON. Some of these areas may never have surface flooding but they have high water tables that fluctuate with the balance of gains and losses of water. They are the interface between the water that we're trying to protect and the agricultural activity or the urban setting or whatever that is generating the sediments, the nutrients, and possible toxic compounds.

It has been shown in several studies that as much as 90 to 95 percent, for example, of the nitrate nitrogen that comes from agricultural runoff is removed by the seasonal wetlands. Sediment removal may be on the order of 50 to 70 percent. We've got numbers on these. (Documentation can be found in my written testimony.)

It is unquestionable that these wetlands are extremely valuable. One reason that they are so valuable is because there are so many of them. They are the most numerous of streams in terms of headwater versus higher order streams. They are, in a sense, the first front across which pollutants and nutrients pass in order to get into the water.

One of the problems is that these wetlands are not very well protected, as you might know. There is a nationwide permit (number 26) that says that wetlands in waters that have a discharge of less than five cubic feet per second are covered in this nationwide permit. This is tantamount to saying that they are unregulated. From a water quality standpoint, the ones that have the most importance are the ones that are the least regulated.

Senator BAUCUS. Are there values other than pollution prevention in headwater wetlands?

Mr. BRINSON. The other values go along with water quality is wildlife habitat. These are quarters for wildlife, and the amphibians and reptiles that Dr. Larson mentioned are certainly important in those areas. Often, in an agricultural or urban landscape, they are the only highly structured habitat in terms of forests for songbirds and other wildlife that contribute to regional biodiversity.

Senator BAUCUS. Dr. Hubbard.

Mr. HUBBARD. May I add something to what Dr. Brinson said?

Senator BAUCUS. Surely.

Mr. HUBBARD. In terms of the nutrient functions of prairie wetlands, which I had not discussed yet, the science is still in its infan-

cy out there. But based on what we know about other parts of the country and based on at least one Prairie Pothole Region study, they are also very important for controlling fertilizer runoff from agricultural fields.

In the one study done in Iowa on a semi-permanent marsh, it was found that about 78 percent of all the nitrogen in the runoff water coming off the surrounding agricultural fields was de-nitrified and essentially cleansed out of the runoff water within the marsh before it ran out of the stream at the downstream end of that particular wetland.

Now, we have not done any studies on temporary and seasonal wetlands to evaluate the pollution control function of them on the prairies, but I speculate based on what we know in other regions of the country, that it is substantial. First off, most of these small depressions are dead-end basins. They only rarely overflow, so most nutrients running into them stay there. Once they become ditched and drained for agricultural production, they have then become a possible liability in that the runoff that used to be held there where the nitrogen could be de-nitrified shot right back up into the atmosphere. It no longer gets to hold there and shoots right down through the system where it enters our lakes and rivers and things like that.

Senator BAUCUS. You addressed the question of seasonal wetlands. I wonder if Dr. Brinson and Dr. Larson could also address the point that some make that seasonal wetlands, because they are seasonal, are much less important. I am just curious of your scientific view of that.

Mr. LARSON. Well, that kind of approach is kind of a meat ax approach because wetlands have different functions. You cannot just simply say that because one has one hydrologic regime and another has another hydrologic regime that one automatically is low value and the other is high value.

I would agree entirely with Dr. Brinson's assessment of the value of the seasonal wetlands in terms of nutrient control and water quality in the Northeast. That is not a duck test. Leave the duck test to the ducks. For water quality, very important.

Mr. BRINSON. I think that this problem derives from the fact of the public perception of what a wetland is. Until we started studying these areas, we didn't know the functions of the headwater streams, for example, and didn't realize the extent to which they were capable of removing pollutants. We were mostly concerned about wetlands and waterfowl. For waterfowl, you need standing water, so it is a whole new dimension that the functions of wetlands have taken. It is so germane to the goals of the Clean Water Act that it just cannot be ignored.

Senator BAUCUS. Dr. Larson, what about developing a priority ranking system to assign relative functions and values? Is that possible without going out and visibly conducting some on-site inspection?

Mr. LARSON. For planning purposes, yes. Many of us have been involved in developing procedures for predicting the probability of a certain function being present on the site or not. But if you are going to make a regulatory decision, you need quantitative information on how that wetland functions.

Maybe an analogy could be taken from forestry. I am a forester. I need to have a map that shows where the forests are. Then I would like to know what is growing in those forests. But I don't make a forest management decision just because I know where the white pine and the hemlock and the long-leaf pine are. I have to go out on the site and find out what kind of growth rates and what kind of soil conditions are there.

To move to assessment as a regulatory tool, you would have to have more detailed information than we have in the current procedures or from those that would be available in the next 18 months.

Senator BAUCUS. I have no further questions.

Do any of you have something you would like to say?

Mr. BRINSON. I would just like to follow up. It seems that our perceptions of wetlands are these fairly pristine areas that are unimpacted, when in fact, many of the areas that are under a lot of stress are still carrying out these functions.

In any ranking system, it may look like a degraded wetland that is not working when, in fact, from a water quality standpoint, it could be working to capacity.

Senator BAUCUS. For example—somebody is driving along a road and sees one of these areas and thinks it's not working, not doing very much, but it may be. What would one of these areas look like?

Mr. BRINSON. Well, some of the wetlands in urban areas that have washing machines dumped in them, for example——

Senator BAUCUS. Most.

Mr. BRINSON. —the washing machine may cause some to say that this is an impacted wetland and, therefore, it's got a lower value than one that is entirely pristine and does not have washing machines in it. Also, when timber is removed from some areas, they look horrible for the next several years. They look like they are highly degraded wetlands because there are trees fallen and there are ruts and so forth. From a water quality standpoint, they are still functioning and they are still contributing to making the waters much more nutrient free and sediment free.

Senator BAUCUS. Thank you very much.

Mr. LARSON. I would just like to compliment the committee on focusing on these groups of wetlands. They are not obviously marshes filled with waterfowl and swans and the like.

I would suggest that the saturated wetlands may be the wetlands that are most relevant to the core of the Clean Water Act. The Clean Water Act is not meant to be a wildlife, waterfowl act. It is looking at water quality, water quantity, and these saturated wetlands may indeed be among the most important for that particular set of functions.

Senator BAUCUS. OK.

Mr. HUBBARD. I would like to add also that the temporary and seasonal wetlands may be, even though we have a lack of direct research information on them, the most important for water quality functions also in terms of the types of clays and the alkaline conditions found in them, regardless of the fact that they might be tilled through every couple of years and planted with crops and the vegetation destroyed. They still have hydrological function. They still have nutrient detention functions, and they still even have wildlife functions as well.

If you come out in the springtime to the prairie, those wetlands are all black dirt. Yet they fill with water in the spring and are used by an awful lot of birds.

Senator BAUCUS. OK; thank you very much. I appreciate your testimony.

Our next panel consists of Dr. Mary Kentula, Dr. Joy Zedler, and Dr. Russell Lea. Dr. Kentula is with the Environmental Protection Agency in Corvallis, Oregon. Dr. Joy Zedler is with the Biology Department at San Diego State, and Dr. Russell Lea is with the Hardwood Research Cooperative, North Carolina State University in Raleigh, North Carolina.

Dr. Kentula.

STATEMENT OF MARY E. KENTULA, U.S. ENVIRONMENTAL PROTECTION AGENCY, ENVIRONMENTAL RESEARCH LABORATORY, CORVALLIS, OR

Ms. KENTULA. Good morning, Mr. Chairman. I am very pleased to come before you to speak about wetland creation and restoration.

As you very well stated at the beginning of this hearing, wetlands are important features of the landscape, often acting to improve water quality, store floodwaters, or provide vital habitat. Therefore, the ability to create and restore wetlands is crucial to maintaining the quality and quantity of the wetland resource.

The most current assessment of the ability to create and restore wetlands was recently completed and published as part of EPA's Wetlands Research Program. That document, "Wetland Creation and Restoration: the Status of the Science," reports the status of wetland creation and restoration by region and wetland type and discusses wetland creation and restoration in relation to topics in ecology and resource management.

I will begin my discussion by briefly summarizing the major findings of the report. The details of my testimony are presented in the written text that was submitted.

The first general conclusion reached in the report was that practical experience and the available scientific knowledge on restoration and creation are limited for most types of wetlands. The amount of information also varies regionally and with wetland function of interest.

It is probably impossible to exactly replicate any given wetland through creation or restoration since natural systems are very complex and highly variable. The subtle relationships of water, soils, vegetation, animal life, and nutrients, which may have developed over hundreds of years in natural systems, have not been totally identified, let alone studied in the context of restoration and creation. Nevertheless, experience to date suggests that some types of wetlands can be approximated and certain wetland functions can be restored, created, or enhanced.

The amount of information available on wetland creation and restoration varies by wetland type and the region of the country being considered. The most is known about the creation and restoration of the smooth cordgrass marshes of the low intertidal regions of the Atlantic Coast. Less is known about creating and re-

storing wetlands on the Gulf and Pacific Coasts. By far, however, the least is known about restoring and creating inland freshwater wetlands.

The information available also varies by the wetland function of interest. Most is known about creating and restoring the flood control and the waterfowl production functions of wetlands. The least in known about some of the water quality improvement functions and the groundwater recharge and discharge function.

The second general conclusion reached in the report is that most wetland creation and restoration projects do not have specified goals and that this complicates efforts to evaluate success. Project goals seldom have been specified, even in cases where wetlands have been intentionally restored or created. Partial failures are common.

Success often depends on expertise and project design and on careful project supervision. It also depends on the long- term ability to manage, protect, and manipulate the wetlands and adjacent areas. Restored or created wetlands should be designed as self-sustaining or self-managing systems unless the project manager clearly has the incentive and capability for long-term management.

The third general conclusion reached in the report was that monitoring of wetland creation and restoration projects has been uncommon. Most investigations of wetland creation and restoration have been short-term case studies with little quantitative data and no comparisons with natural systems.

Those investigations that have rated the success of wetland creation projects most often do so on the basis of compliance with permit requirements as opposed to replacement of function. More detailed and longer-term monitoring is required to determine if wetland functions are being replaced over the long term.

Results from EPA studies too recent to be included in the status report show that many of the differences between created and natural freshwater systems can be related to the relative differences in the ages of the sites. However, one potentially important difference between the created and natural systems was that they differ structurally and hydrologically.

For example, created systems have significantly more open water than similar natural systems in the regions studied. This means that the wetlands being created are different than the wetlands found in the regions and that changes in the relative proportions of wetland types in an area are occurring due to compensatory mitigation required under Section 404 of the Clean Water Act.

Results of an EPA study in Oregon indicated that none of the wetlands evaluated were constructed as either designed or permitted. Twenty-nine percent less wetland area was created than was required in the permits. In 45 percent of the sites, the slopes listed in the plans and as built were steeper than the maximum recommended in the literature. The steep slopes caused a large proportion of the sites to be dominated by open water rather than vegetation. The vegetation planned to be planted on the site did not occur on the sites.

In summary, because the knowledge on wetland creation and restoration is fragmented and incomplete, proposals to create or restore wetlands should be reviewed with care. This is especially true

when restoration or creation is proposed in exchange for the destruction of an existing wetland.

In evaluating such proposals, both the importance of the ecological role of the wetland locally and in the surrounding landscape as well as the probability that the creation or restoration project will succeed should be taken into consideration. The amount of risk associated with the creation or restoration project should be reflected in the stringency of design requirements, compensation area ratios, and performance criteria.

In general, restoration should be favored over creation. Restoration of a damaged or destroyed wetland will have a greater chance of recreating the range of prior wetland functions and of persisting over the long term.

Mr. Chairman, this completes my statement.

Senator BAUCUS. Thank you very much.

Next is Dr. Zedler.

STATEMENT OF DR. JOY B. ZEDLER, BIOLOGY DEPARTMENT, SAN DIEGO STATE UNIVERSITY, SAN DIEGO, CALIFORNIA

Ms. ZEDLER. I am responding to the general question: do man-made wetlands replace natural wetlands, such as this one? Our answer is based on a 20-year research program that has sought to understand Southern California's coastal salt marshes. In includes the work of many associates and graduate students. The California Sea Grant Program has funded much of our research and recently published this manual on assessing restored and natural wetlands.

San Diego Bay's man-made wetlands include eight small islands at the Sweetwater Marsh National Wildlife Refuge and a 55-acre dredge spoil island known as the Chula Vista Wildlife Reserve. All of these islands were built over six years ago. They comprise two mitigation projects. They were constructed to compensate for the loss of natural salt marsh habitat that supported endangered species. Some of that natural habitat is shown here.

We would be able to say that man-made wetlands replace natural wetlands if they have the appropriate species, if they have the required functions, and if they are able to persist in perpetuity.

So, do they support the desired native species? No. Several are missing. The tall cordgrass vegetation is missing. Cordgrass grows on these islands, but it is too short. The Light-footed Clapper Rail is missing. This is an endangered bird for which the islands were designed. Marsh invertebrates are not abundant enough. Predatory insects that control herbivores are too rare, and an endangered plant is missing.

This is the Rail. It needs the tall plants and the invertebrate foods. These are the native beetles that are needed to control plant-eating insects, and these are the scale insects that grow in abundance and kill the plants when those native beetles are absent. This is the annual plant that is endangered. We cannot get it to establish on these man-made islands. In summary, several critical species are not sustained by these man-made wetlands.

Do the man-made marshes function as well as the natural wetlands? No. Pollination is impaired. We were able to get the seedlings of the endangered plant to grow on the island, but as an

annual, it needs to be pollinated. Without pollination, it doesn't produce seeds and there is no future for the species.

Food chain support appears to be impaired. High tide refuges are lacking. Predator protection for birds is inadequate. Nesting habitat is in adequate. Short plants just don't do the job. Plant growth is impaired because the cordgrass does not get enough nitrogen. We concluded that man-made marshes were less than 60 percent functionally equivalent to the natural reference marsh.

This illustrates how poorly the six year old island functions as habitat. The tops of the islands are bare and the plants around the edges are too short. When the tide is high, everything you see in this slide disappears as it's covered by water. Insects must either leave or drown.

The Clapper Rail, the endangered bird, has a nest that floats when the tide rises. If the birds were to build their nests in this short grass, the nest would float through the canopy and expose the eggs or chicks to predators.

Given these shortcomings in functioning, are these man- made marshes likely to improve and persist? No. They cannot mature fast enough. They are not self-sustaining. They are too easily invaded by exotic species. They will succumb to accelerated levels of sea level rise. They are too small and too isolated. They are really much more like "wetland gardens" that need constant maintenance.

Now some people claim that they can build wetlands that can compensate for further habitat loss. They probably do know how to replace a few species of plants, but they have very little information on functions and no evidence that those sites can persist. Our research on Southern California wetlands shows that we cannot yet replace natural salt marshes.

Where we examined biodiversity, we found a net loss. Where we studied wetland functioning, we found a net loss. These sites are unlikely to persist or to sustain regional biodiversity. So, if decision-makers continue to permit wetland habitat destruction on the promise that damages can be mitigated, our current biodiversity crisis will only be heightened.

Thank you for your attention.

Senator BAUCUS. Thank you.

Dr. Lea.

STATEMENT OF RUSSELL LEA, HARDWOOD RESEARCH COOPERATIVE, NORTH CAROLINA STATE UNIVERSITY, RALEIGH, NORTH CAROLINA

Mr. LEA. Mr. Chairman and distinguished committee members, it is certainly a pleasure to be here to testify today, and this testimony will focus on the methods used to restore or create forested wetlands in the Southeast. You may want to keep the room darkened because I will be using slides in a minute.

Senator BAUCUS. OK.

Mr. LEA. I also want to provide some of my opinions on functional equivalency of restored wetlands.

Construction and scientific monitoring of mitigation sites can assist the basic research needs of regulatory agencies. If scientifi-

cally proven to be successful, mitigation efforts can indeed be a valuable tool in carrying out the Clean Water Act mandate to restore and to maintain the chemical, physical, and biological integrity of the Nation's waters.

Mitigation efforts in general may effectively restore some of the Nation's wetlands and even perhaps eventually create healthy, functioning new wetlands. Hundreds, perhaps thousands of coastal and estuary mitigation projects have been constructed along the Eastern Seaboard. These projects have been subject to a fair amount of follow up monitoring and have been widely reported in literature. In contrast, much less is known about the amount of inland bottomland hardwood restoration and creation projects where success is less certain and the timetable for success is more variable.

This is an initial effort to create marsh on Eastern North Carolina. As you can see, you can get some functional equivalency of replacement. There are certainly other functions that are not apparent at that time of replacement, but it's form over function and there is certainly a form that is emerging there. Function, perhaps, will follow.

What we have not talked about is the complexity of bottomland hardwoods. Certainly there are different kinds of forms and different kinds of functions that we have to deal with and a different length or span of time that we have to deal with.

Next is a different type of bottomland hardwood type of system with open water adjacent, and another, and finally another, a cypress stand. What I have not told you about those preceding slides is that they were all created bottomland hardwood systems, all four of those previous pictures.

We have some history on some created systems. Here is a slide from 1943, I believe, of some people establishing bottomland hardwoods, and this is what it looks like today. Certainly, the trees are planted in rows; the trees are regenerating themselves, as you can see in the middles, so there is some form and some functions provided by efforts that have gone on in the past. What we don't know is to what degree the functions have been achieved to natural systems and, furthermore, we don't know whether some of these created systems are better than what was there originally.

This is often the landscape that we are using to create bottomland hardwood restorations in the Southeast, so when you start talking about soils and hydrology, you often are starting from ground zero. This is the kind of place that we are to mitigate to bottomland hardwoods or to restore. It's very challenging.

Here is an urban setting right in the Research Triangle Park of North Carolina. That is to be developed and we are to mitigate for that kind of activity as you see right there.

There is another kind of mitigation. That is restoration of a system that is in trouble. These may be a little bit easier to deal with because we are not dealing with a new soil. We may simply be dealing with an altered hydrology which would take a minor manipulation and possibly some tree planting to bring back to original functions.

Here is a thermally impacted area at the Savannah River site. Again, if we would discontinue the thermal impacts, the soils may be intact, the vegetation may be possibly restored.

What do we do when we face a wetland site that needs something done to it? Here is a site that has been languishing for years with no apparent good coming about other than eroding and having little or no connectivity to other functions. What you try to do is to try to make sure that you create a wetland—for example, you have wet soil; you have wetland species established in that wet soil; and hopefully, given that you've achieved that, you would create a functional wetland. Presto—you may be able to get some of those tree species that we would be endeared to.

However, there are problems associated with just putting trees out on wet soils. There is a lack of knowledge of what kinds of trees to plant and what kind of forms to plant. You are not going to grow successful trees when they don't have roots. Here is one about which it was questioned: why did this tree die? When you look at the root system, it never had one to start with.

What we try to do now is try to visualize the wetland restoration and creation using computer-aided design. We are dealing with multi-dimensions of spacial dimensions, of water dimensions, and of tree dimensions and trying to put that in a visual context so that we can interface those on a computer screen before we ever go out and start scraping earth. Here is another computer visualization of a created wetland.

Hopefully if we got everything right and everything comes together, we can provide wetlands of this kind. Again, that is also a created wetland of a cypress stand. We are currently trying to assess what functions that it might be providing in the long run.

Thank you.

Senator BAUCUS. Thank you all very much.

I guess the first question that comes to my mind is the degree to which creation works or can work. Do any of you know? Dr. Lea talked about the hardwood wetlands. Are those all created or is that restored?

Mr. LEA. It was a mixture of created and restored wetlands shown there. Those first four original slides of those wetlands were all created wetland. Creation in the terms I'm using means new soil, new hydrology, and new plant material.

Senator BAUCUS. What is your best estimate as to how well that will work out in the long run?

Mr. LEA. These, we don't know. We have some of these that are fairly mature, as you saw, with the large diameter trees and fairly mature canopies. But elements of bio- diversity need to be examined and elements of food chain support. Hydrology—these are all questions.

We have a form out there which looks like a forest. To what degree they are performing some of the wetland functions of the natural system needs to be assessed.

Senator BAUCUS. Dr. Zedler, you seemed to indicate, at least in the areas you've studied, that they are not going to work out in the long run. I don't want to put words in your mouth, but that is what I heard from your statement.

Ms. ZEDLER. You heard it correctly. That does not mean that we should not attempt to correct the kinds of problems that we've seen happen in the past. It does not mean that there is no hope.

I think that if I can most clearly represent my attitude, it is that we can attempt many restoration projects and improve the situation for wetlands nationwide, but we can't do it as mitigation for future loss. We could probably learn an enormous amount by attempting wetland restoration and wetland creation.

Most of what we have learned about these systems' function has derived from mistakes made in trying to recreate them. The science of restoration has grown because of problems that developed. We learned about those insects——

Senator BAUCUS. That reminds me that somebody once said that wisdom is experience and experience is mistakes. I think that is probably true of this area, too.

Is there a difference between coastal and inland wetland restoration or creation? Is one more likely to be successful compared to the other? I think you indicated that not much is known about inland wetland restoration and creation.

Ms. KENTULA. I would say that in general, it is more difficult to create the inland wetlands.

Senator BAUCUS. Why is that?

Ms. KENTULA. Because the hydrology is much more difficult to reestablish.

Senator BAUCUS. Explain that a little bit. What is more difficult about inland hydrology?

Ms. KENTULA. In the case of tidal systems, you have the ocean putting the water there periodically, the tides. If you get your elevations correct and you are in an area where the tides have access and can bring the water in at the right intervals, then you have a high probability that you'll get a wetland established. Because you have that tidal influence, coastal wetlands tend to be easier.

For inland wetlands, you have the problem of getting water to the site—I would guess that the ones that are most successful are those that are connected to surface water. For instance, if you have a stream coming into an area, you have a source of water. The wetlands that are most difficult to create or restore are those that are tied into the groundwater system, like the prairie pothole wetlands that Dr. Hubbard talked about, because we don't understand how the groundwater system works, so to try to replicate it or recreate it is very difficult.

Senator BAUCUS. Among the various values of wetlands, wildlife, environmental, hydrological, are any of those three more likely to be accomplished through restoration or creation compared with the others?

Ms. KENTULA. Again, that depends on the wetland type and where it is located. You may have a wetland that looks like it would provide tremendous habitat, but if it is isolated from other natural systems, it may have little habitat value in reality. Where you locate that wetland and how it is connected to other systems is very important. It is important not to isolate them.

Senator BAUCUS. Do you all agree that wetland restoration can never fully replace wetland that we destroyed or adversely impacted; is that correct?

Ms. ZEDLER. I would certainly agree. So many of the landscape features that support wetland habitats are lacking. We have now a lot of exotic species in the landscape and when you try to create a system, there is a likelihood that it will be invaded by non-native species. Therefore, those species will affect the other natives and it may be impossible to recreate the system that developed over centuries in the absence of those outsiders.

Senator BAUCUS. And all projects that destroy wetlands, in your view, will likely cause some net loss even if compensatory mitigation is required?

Ms. ZEDLER. I agree, yes.

Senator BAUCUS. Do the other two of you agree or disagree with that assessment?

Mr. LEA. I would have to add that if you take a proactive response, there are some wetlands that will be endangered of ever being a wetland in the future. The hydrology may be cut off. Urbanization may preclude their future value as a wetland just from the physical forces removing the energies that have created that wetland.

For example, the hydrology. In that instance, if you take a proactive response and you identify other wetlands that may be limping along but they are in the watershed and in a relatively protected area, such as green-space areas or corridors or some of these riparian greenways that we have intersecting and bisecting our cities, then we could place our efforts onto some of those and bring them back to a more functional state. That takes an assessment of and a certain knowledge of what these wetlands are doing and what is happening in a surrounding cumulative impact sense.

Senator BAUCUS. Dr. Kentula.

Ms. KENTULA. I would agree. First of all, I would like to say that when you say absolutely no, they are never going to come back, I would like to echo something that we all said. That is that right now, we don't know.

The vast majority of these projects are five years of age or less. That makes saying absolutely a little hard. I am uncomfortable saying that. I think that in some cases, that answer is absolutely not, but I think Russ makes a good point about viewing the role of the wetlands in the landscape and the relative risks to the functions that you are interested in.

I know of cases where wetlands have been protected from development. I know of cases where the shopping center was moved to preserve a wetland, and when one went back in a couple of years, the wetland has disappeared because the hydrology was altered by that development, even though the wetland itself was not built in.

One of the things that I think we need to decide up front is: can we afford to lose that wetland? Are we losing something that is valuable for the functioning of that landscape? Secondly: how can we best maintain the resources we have? At the same time, we need to try to increase the resource base.

Senator BAUCUS. Thank you.

Senator Chafee.

OPENING STATEMENT OF HON. JOHN H. CHAFEE, U.S. SENATOR FROM THE STATE OF RHODE ISLAND

Senator CHAFEE. Thank you, Mr. Chairman.

I apologize for not being here. We had a very important hearing in the Banking Committee dealing with a situation pertaining to Rhode Island. That started at 9:45 and we just now finished our testimony. So we were occupied there, regrettably, and could not be at this hearing which I commend you for holding.

I'll just put my statement in the record and ask a few questions.

[Senator Chafee's statement follows:]

OPENING STATEMENT OF HON. JOHN H. CHAFEE, U.S. SENATOR FROM THE STATE OF RHODE ISLAND

Mr. Chairman, thank you for scheduling this hearing on wetland functions and values and restoration efforts.

It is proper that our first hearing on wetlands focuses on scientific and technical issues. I fear that as the controversy over wetlands issues heightens, there may be a tendency for ecological considerations to be given short shrift. This hearing provides an important opportunity to review and reaffirm the unique contribution to the quality of our lives made by natural wetland ecosystems.

While there is consensus on the value of wetlands in a general sense, there is still much controversy, or at least confusion, over the importance of certain types of wetlands—such as, seasonal wetlands, saturated wetlands, and altered wetlands. We need to take great care to ensure that entire categories of wetlands are not hastily written off as "marginal" or unimportant because their functions are not readily apparent. We cannot decide which wetlands should be given priority attention by applying something as simple as a "duck test." Often, there is much more to a wetland than meets the eye.

As well, an examination of the successes and failures of efforts to restore or create wetlands is essential as we consider the feasibility of "offsetting" wetlands losses. It does little good to compensate for loss of natural wetlands by creating wetlands if these new wetlands do not provide similar or equivalent functions and values. With wetlands still being destroyed at a rate of several hundred thousand acres per year, this issue takes on increasing importance as each year passes.

The Environmental Protection Subcommittee is well-versed on the extraordinary value of these unique ecosystems which support countless species of fish, wildlife and birds, and perform critical functions for water quality and quantity, storm buffer and flood control. The protection of wetlands is a top priority. As this Subcommittee continues to examine the effect of our laws and activities on our Nation's precious wetlands resource, we will draw upon the testimony presented today by expert ecologists and scientists.

I look forward to hearing from our witnesses.

Senator CHAFEE. I think that all the discussion today is going to involve the most contentious part of the reauthorization of the Clean Water Act, namely section 404. Whether it's prairie potholes or shopping centers or whatever it is, the question is going to be: Can you create these wetlands or restore them.

Just the brief time I have been here today and what I read yesterday indicates that that is not so easy. Certainly, the creation of them isn't. The restoration in itself is a tremendously difficult job.

So I look forward to the testimony and, again, commend you, Mr. Chairman, for holding this hearing.

Senator BAUCUS. Thank you, Senator. You are absolutely correct. When we get into 404, we are going to have, in the expression you often use, some rough weather.

[Laughter.]

Senator BAUCUS. The point of this hearing is to nail down as best we can the science of wetlands and problems and benefits of resto-

ration and creation. As you know, we are going to have subsequent hearings that will delve into the policy.

Senator CHAFEE. Could I just ask one question? Maybe this has been addressed.

One of the matters that is going to come up in 404 and in the whole wetlands area is the classification. This is A category, extremely important. This is B, much more marginal; you can't tell. This isn't really wetland, and so forth.

Is there general agreement within the scientific community? Maybe this question has been answered.

Senator BAUCUS. We've wrestled with it, but you should ask it again.

Senator CHAFEE. All right; I'll see if we get the same answer.

Senator BAUCUS. Right.

[Laughter.]

Senator CHAFEE. Here's the question. Is there a general agreement within the scientific community—and each of these distinguished witnesses is from the scientific community—as to whether wetlands may be classified according to their functional values?

Ms. ZEDLER. I believe there is widespread agreement that that is a very dangerous thing to do. I would agree with the classification if you made them all an A.

[Laughter.]

Senator CHAFEE. Well, we've got a real "enviro" here before us.

Ms. ZEDLER. The scientific evidence is that this is an extremely difficult "apples and oranges" kind of comparison. Without the scientific knowledge to say which is better, apples or oranges, then I believe the risk should be taken by something other than the resource.

We have to start by giving them all an A on the basis of the scientific information. Then the burden of proof should be elsewhere to show that they are less than an A.

Senator CHAFEE. Dr. Kentula.

Ms. KENTULA. I would like to agree with one of the points that was made by the previous panel. That is that a classification system based on wetland type is not doable. Again, the value of that wetland very often is associated with where it is located, as Dr. Brinson said earlier, in that network of systems that form our landscape.

I think that at the practical level, we have something tough that you are trying to deal with. I will offer some of the thinking that we have had in the Wetlands Research Program.

First of all, we feel that classification based on wetland type is not workable and is not ecologically sound, but we feel that in order to manage the resource that, perhaps, a risk-based approach management would assist in helping make decisions. We have been developing some tools whereby—and we would start from the top down—we can find areas in the landscape that are threatened due to wetland loss or that are particularly important for particular functions.

We have developed what is called a synoptic assessment methodology where you can rank watersheds relative to each other for different functions. We don't say that this one is the best of the worst. That is left to the policy-makers to decide, what is good and what is

bad. You start that way, find out where your critical areas are, where wetland functions are at risk, where your greatest losses have been and then concentrate your management resources on those areas.

Those are the areas where you really need to be tough about requests for permitting and really concentrate your resources. We would advise starting with that sort of ranking, if that is the way it has to go.

Senator CHAFEE. You say put your preventive resources?

Ms. KENTULA. Yes; then your management resources. If you're going to fight a case—that's the area where you need to decide to put your legal resources.

Senator CHAFEE. Draw the line there?

Ms. KENTULA. Yes.

Senator CHAFEE. I don't want to hold you up, Senator Baucus, but I have one question of Dr. Lea.

Dr. Lea, you were showing a slide, just as I came in dealing with the research triangle area and I didn't quite get all that you were saying. Were you saying that to develop the research triangle you had to take over some wetlands?

Mr. LEA. No. I was showing a slide of an urban impact in the Research Triangle area, but we also—if you're talking about extension and development relative to educational processes—we are also trying to accomplish that at North Carolina State, trying to train whoever desires such training in restoration ecology as a general practice.

I would like to provide some testimony relative to the classification. If you're looking for a taxonomy of wetlands, there is no question that you can classify——

Senator CHAFEE. What's that word again?

Mr. LEA. Taxonomy.

Senator CHAFEE. What does that mean?

Mr. LEA. It would be a way of classifying a system based on its attributes. If you classify soils—all the soils in the United States have been classified by SCS. There is a taxonomic key by which you determine what kind of properties constitute a given soil of a given genetic type.

If you are just looking for taxonomy of wetlands, there is no question that you can classify wetlands based on a taxonomy. But once you have a taxonomy, then you are getting into a value judgement. What are going to do with the soil? Do you plant corn or urbanize it or do something else with it? That's a value judgment.

So if you are looking for just a taxonomy, we could provide a taxonomy of wetlands. The value judgment of whether those attributes are important for urbanization or important for food chain support or water quality—those are value judgments and policy issues.

Senator CHAFEE. Here's the typical problem we have. I was just down in Louisiana the other day. One of the great acquisitions we've made, Bayou Savauge, is right there within the city environs of New Orleans, which must be one of the largest cities, geographically, in our country. In any event, this bayou, I believe, was 20,000 acres or something very significant like that.

The problem comes as follows. They point out a series of trees—and we didn't walk on the soil, but the soil seemed rather firm. It wasn't wet.

That, because of some characterization due to the hydrology and the water levels and the soil and so forth, is classified as a wetland. So the question is: so much of Louisiana falls into that category; surely you're not going to stand by this foolish classification and keep progress from coming to Louisiana? That is the argument that is being made.

Yet, I suppose that even though this particular stand that we were looking at didn't seem to fit the traditional definition of a wetland, the fact that it qualifies as a wetland means that it has all these attributes that we believe are important to nature and to wildlife and fish for our country.

My question is: is there a difference? In other words, when you look at a wetland, as you showed pictures here, dumping fill in that particular area would be an obvious catastrophe; whereas, cutting down some of these trees in the stands that did not seem to appear to be wetlands looked to me to be far less of a major mistake. Am I wrong?

Mr. LEA. That is certainly a decision—an individual seeking to develop a piece of land, that would be jurisdictional wetland, which is a definition assigned to soils and vegetation and hydrology. That individual has certainly a process which he has to follow, the 404 process, to try to seek an activity, if it's a filling activity, that he would desire to do something with that piece of land.

Once he gets through that process, if he can show avoidance and minimization, public interest, then certainly an applicant should be entitled to development providing compensatory mitigation and other measures such as Clean Water.

Senator CHAFEE. Except it seems to me that the testimony here has been that the mitigation, either the recreation or the preservation or the restoration don't work very well. Isn't that what your testimony was?

Mr. LEA. Exactly.

Senator CHAFEE. So when somebody says they're going to cut down this woodland and make a nice parking lot, if that's not a contradiction in terms, and say they're going to do mitigation, in effect, they are not going to do mitigation; is that right?

Mr. LEA. Often that's the case.

Senator CHAFEE. Often? Can you tell me when it isn't?

Mr. LEA. I think there have been examples of some lands which are essentially a restoration project, where you have hydrology intact, you have soils intact, and through programs such as CRP programs, Conservation Reserve Programs, where you establish trees on floodplains and native vegetative plantings in areas where you have hydrology that is natural or relatively natural and soils which are not severely degraded. Then you stand a very low risk of putting a vegetative community out there, such as a forested community. Now, that was still a wetland as you started the process of re- vegetating because you had soils and you had hydrology, but in those instances there is a fairly low risk of obtaining success.

Senator CHAFEE. I am not sure I understood that answer.

Senator BAUCUS. I have a question for you, Dr. Lea. Classification, at least for the purposes of SCS, that they can at least classify these wetlands. As I understand it, the present classification is done by, what, NASA overflights or U–2s or something? Based upon the overflights, these wetlands are mapped out. That's all that is done right now basically. Is that correct or not correct?

Mr. LEA. I think I'll defer to Dr. Kentula for that answer, but there is ground-truthing and well as overflight, certainly. There are on-the-ground assessments made.

Senator BAUCUS. But to the degree that it is only overflights, that is not going to tell us very much, as I understand it.

Ms. KENTULA. Yes, there are wetlands that are missed, particularly the small ones, with the aerial photography. The Fish and Wildlife Service is the organization that produces these maps, and they do ground-truth. Again, they are not the answer.

Senator BAUCUS. But the overflights and those other assessments won't tell you very much about their functions?

Ms. KENTULA. No, nothing. It will just give you some idea where wetlands might exist.

Senator BAUCUS. That is what I'm trying to get at.

Another quick question is: how long is long enough to know whether created wetlands will be successful? How long do we have to wait and study to know?

Ms. ZEDLER. Unfortunately, in our study, which was a two-year assessment, things did not improve in that two-year time period and, as Dr. Kentula says, most of these sites are fairly young. They have been assessed for even shorter periods of time, so it is tough for scientists to say when they might show improvement. I think that perhaps we have to plan in a 30-year time frame.

If I could speak on the policy side for just a bit—Mr. Chafee was asking: isn't there something that can be done that would show that mitigation would work? Up-front mitigation prior to destruction is a "show me" type of strategy. If somebody can go to a site and construct a wetland and show me in 5 years or 10 years that they have something that functions as well as or better than the other site, and if they would also assess the functions of that site—the problem is that now neither happens. They don't assess the functions of the site to be developed. They will look at the structure, not the functions. And then they promise a restoration site that is going to be better and it isn't.

Senator BAUCUS. Well, I appreciate this very much. You've been very helpful to me and, I know, to other members of the committee.

This concludes this hearing. Thank you very much for coming here.

[Whereupon, at 11:48 a.m., the subcommittee adjourned, to reconvene at the call of the Chair.]

[Statements submitted for the record follow:]

PREPARED STATEMENT OF DANIEL E. HUBBARD, PH.D.

The Prairie Pothole Region (PPR) is an area of glaciated landscapes in northcentral North America. The PPR extends from northcentral Iowa and western Minnesota, through those parts of the Dakotas east and north of the Missouri River, across the northern portion of Montana, and well into the provinces of Manitoba,

Saskatchewan, and Alberta. The numerous depressions (termed "potholes" by biologists) left behind by the glaciers periodically fill with water, forming wetlands primarily of the Palustrine System with varying water-regimes. The PPR is the single most important area for breeding waterfowl, especially dabbling ducks (Anas spp.), on the North American continent. In a typical year, over half of all dabbling ducks on the continent are raised in the PPR.

Many of the wetlands in the PPR have been drained for agricultural production. Over 95 percent of the natural wetlands in Iowa have been drained and it has been estimated that about 70 percent, 35 percent, and 60 percent of the wetland area in the PPR portions of Minnesota, South Dakota, and North Dakota, respectively, has been drained. Although much of the drainage has been done in order to increase tillable acres, presently much of the drainage is being conducted merely to make agricultural production easier. The large equipment used by modern farmers are less maneuverable than the small equipment of the past thereby making it more difficult to steer around the small wetlands that are scattered in the fields. These are often referred to as nuisance "wet spots".

Most prairie pothole wetlands can be classified into 3 types: temporary wetlands, seasonal wetlands, and semipermanent wetlands. However, ephemeral wetlands, permanent wetlands, intermittent alkali wetlands, and fen wetlands also occur. Those wetlands of the temporary and seasonal categories are the ones most often contested by landowners as being wetlands.

Temporary wetlands are characterized by only being ponded with water for only about 1 week to a month or more in years of "average" runoff. Seasonal wetlands typically contain ponded water for at least a month but usually never for the duration of the growing season in an "average" runoff year. Semipermanent wetlands, though, are typically wet for the majority of the growing season in an "average" runoff year. Almost always, these 3 kinds of wetlands will be considered as wetland under the Federal guidelines for jurisdictional wetlands. Ephemeral wetlands, on the other hand, will rarely (if ever) meet the Federal jurisdictional guidelines because they usually are only wet for just a few days and rarely support hydrophytes of any kind. I will not deal with these ephemeral wetlands in my following discussion. The descriptors I am using in this discussion follow those found in a publication by Stewart and Kantrud (Stewart, R. E., and H. A. Kantrud. 1971. Classification of natural ponds and lakes in the glaciated prairie region. U.S. Fish Wildl. Serv. Resour. Pub. 92) and is compatible with the water regimes descriptors found in a publication by Cowardin et al. (Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deep water habitats of the United States. U.S. Fish Wildl. Serv., Biol. Serv. Prog. FWS/OBS–79/31). This latter publication is the classification system used by the U.S. Fish and Wildlife Service's National Wetland Inventory.

It is extremely important to keep in mind that "average", when referring to weather in the PPR, is almost an abstract term. In this region, extremes of both temperature and precipitation are the norm. To understand why this is important, one must understand the hydrology of these wetlands.

Pothole wetlands receive their water from either direct precipitation, meltwater from drifted snow, runoff from surrounding uplands, or by groundwater discharge. Water leaves a prairie pothole by either direct evapotranspiration (ET) from the pond, marginal ET from the pond edge, groundwater recharge, or by overflow out of the depression during high water levels. Throughout the PPR average annual precipitation is always less than the average annual evaporation. Therefore, it is the amount of water entering a pothole from runoff, meltwater from drifted snow, or groundwater discharge that is in excess of direct precipitation that governs a pond's permanency.

Runoff into potholes occurs during the spring thaw when melting snow or precipitation flows over frozen soil or during the frost-free season when precipitation rates exceed the infiltration capacity of the soil. The glacial till derived soils of the region are high in smectite clays which expand greatly when wet and are the primary cause of low permeabilities of the soils. The amount of runoff that a pothole will receive can vary greatly between years, and the relative contribution of snow-melt runoff and growing-season runoff can also vary greatly. This is also true between localities in the same year. Depending on the intensity and timing of precipitation events, runoff can be high in some years of below average precipitation and, conversely, runoff can be low in some years of above average precipitation.

There are 3 general types of pothole wetlands in regard to groundwater: groundwater recharge wetlands, groundwater discharge wetlands, and flowthrough wetlands that both recharge and discharge groundwater at various locations within the pothole. However, depending on fluctuations in the watertable, a pothole may tem-

porarily change from one type to another. The classification of prairie pothole wetlands can roughly be related to groundwater relationships. It may be generally stated that groundwater recharge wetlands are typically temporary and seasonal wetlands, discharge wetlands can be either semipermanent, intermittent alkali, fen, or permanent wetlands. Flowthrough wetlands are typically semipermanent, and permanent, but some seasonal wetlands may also be flowthrough systems. Most semipermanent and permanent wetlands probably shift between flowthrough and discharge types depending on watertable fluctuations. However, after periods of drought when many semipermanent wetlands are dry, they may even function temporarily as recharge wetlands until watertable levels rebound.

The above discussion on prairie pothole hydrology serves to point out 2 important concepts. The first is that temporary and seasonal wetlands are not always wet. During extended periods of below average runoff they may not contain ponded water for several years. Hence, they are frequently tilled and planted to crops. In fact, in any given year about 50 percent or more of them are cropped in the Dakota's. The second important concept is that all of these wetlands are "windows" to the watertable. I will now elaborate on this point.

Effective recharge to the groundwater in these glaciated landscapes has been theorized to be depression focused (i.e., occurs only where water is ponded, as in temporary and seasonal wetlands). If this is true, then widespread artificial drainage of wetlands, regardless of type of groundwater interactions, should eventually lead to general watertable declines. Consequences of lowered watertables could be lowered heads in domestic wells located in buried outwash in the till and possibly a circumvention of soil moisture recharge from groundwater. However, no studies have been conducted to address the magnitude of these issues. Theoretically, the consequences of lowered watertable have potentially large impacts on region-wide agricultural productivity.

It has been shown that over the course of winter, water can move upward from the watertable to the frozen soil above it in response to thermal gradients in the till soils of the PPR. One study reported soil moisture increases due to this phenomenon of greater than 10 percent at the 60 cm depth at a summit position 80 m from a seasonal wetland in eastern North Dakota. Watertable depths dropped from about 3.7 m to 4.3 m below the soil surface during this soil moisture recharge event. At more shallow watertable depths, soil moisture recharge can be up to 100 percent. The proportion of the landscape in the PPR that receives soil moisture recharge from the watertable is not known, but I speculate that it is substantial. If watertables decline due to artificial drainage of potholes, and this source of soil moisture is precluded, then negative economic impacts of potentially large proportions may occur to crops in this drought-prone region.

The effect of draining wetlands on flooding problems in the PPR is problematic. Experimental documentation of the effect of artificial drainage on flooding problems in the PPR has not been published. However, numerous computer simulation studies and empirical studies provide compelling evidence that the artificial drainage of wetlands in the PPR has probably had major contributory effects on flooding problems in the region in recent decades. The amount of water that can be collectively stored in potholes over an area is large. Likewise, the amount of noncontributory area in PPR watersheds can be impressive, certainly in the millions of acres especially under dry conditions. One hydrological paper has described the fluctuating drainage area phenomenon in detail and provided an example of a watershed that under dry conditions (depression storage empty) had a net drainage area of 20 percent of the net drainage area under wet conditions (depression storage full and wetlands overflowing). If a depressional watershed were to be completely "ditched-out," then the net contributing area will be permanently increased to the size of the "net wet drainage area." The relationship between increasing drainage area and increasing watershed discharges has long been recognized by hydrologists. While the magnitude of the largest flood events may not be changed from the natural condition in an artificially drained PPR watershed, it would seem logical to predict that the magnitude of smaller flood events may increase and the frequencies of all flooding events would increase. The data presented in many studies reveal that these consequences of artificial drainage may indeed have been realized.

Wetlands throughout the U.S. have been purported to act as nutrient (nitrogen and phosphorus) sinks for inflowing waters and have even been used in tertiary wastewater treatment. In the PPR, only a few studies has been conducted on wetland nutrient sink functions. One study looked at water quality in a very large semipermanent wetland. Land use in the watershed was primarily row-crop agriculture (corn and soybeans). They measured nitrogen and phosphorous levels in the incoming and outgoing water throughout an entire drawdown-refill cycle. During the

drought years (3 out of the 4 years studied) there was no water leaving the marsh (via a stream) and the marsh served as a sink for N, P, and soluble organic C. During a wet year when influent and effluent were "normal", the greatest impact of the marshes was on inorganic N, particularly nitrate. The marsh removed 86 percent of the nitrate entering the marsh. Of the inorganic N entering the marsh, 96 percent was nitrate. In regard to ammonium, the marsh removed 78 percent of the amount entering in precipitation and runoff. When one considers that additional ammonium was generated in the marsh by decomposition, the reduction was impressive. They concluded that use of prairie glacial marshes to treat agricultural drainage water can be of most benefit in removing nitrogen.

The marsh studied by those researchers was atypical of many prairie potholes in that it had an outlet for surface water flow. Most potholes only occasionally overflow. Thus, any nutrients in runoff waters are retained in the wetland with the only avenues for leaving being by seepage to groundwater, gaseous loss to the atmosphere, or by animal export. Traditionally, animal export of nutrients has been considered minor but remains poorly studied. Seepage to groundwater of nutrients has likewise not been studied in PPR wetlands. For phosphorus, it would seem that seepage to groundwater would be minimal. For even though phosphorus may become more available to plants during soil inundation accompanied by a decrease in redox potential, its movement out of the wetland via groundwater is likely to be negligible due to the affinity of phosphorus for clay minerals at alkaline pH values. Most prairie wetland soils and the underlying tills are both high in clay and are alkaline. Nitrogen species are affected by microbial transformations that are governed by redox. Nitrate, being very soluble at any redox potential may possibly move out of the bottom of wetlands to groundwater, however to do this, it must escape past the root zone of the hydrophytes, plus the actions of denitrifying bacteria. This has not been studied in PPR wetlands. But the very slow seepage outflow rates for typical seasonal and semipermanent wetlands, 0.0008 to 0.0088 foot per day (0.24 to 2.7 mm per day), make escape of nitrate to groundwater seem unlikely. Due to the lack of research on nutrient movements in prairie wetlands, the nutrient sink functions of these systems can only be speculated upon. However, the conditions in prairie wetlands would indicate that potholes probably act as nutrient sinks—for both phosphorus (merely by simple detention) and nitrogen (by immobilization or gaseous loss). When potholes are drained, however, any nutrient sink functions that potholes may have may be lost. One research study, using regression analyses, investigated the relationship between land use and nutrient output in 34 watersheds in northwestern Iowa. They found that livestock were an identifiable source of phosphorus and ammonium within the studied watersheds. They also found that nitrate in streamflow was negatively related to the percentage of area in the watersheds in wetland. Wetlands likely reduced nitrate because they are areas of anaerobic decomposition, resulting in denitrification and a gaseous loss of nitrogen. Although phosphorus and nitrogen could not be identified with the percentage of the watershed in row crops, grassland, or urban areas, sampling of specific watersheds indicated high nutrient levels in runoff from those areas.

Although more research is needed on the nutrient retention capacity of PPR wetlands, is appears to be highly likely that their drainage could lead to more severe eutrophication problems in our area's lakes and streams. This not only would lead to water based recreation problems, but also could lead to increased costs of water purification for municipalities.

Lastly, I would like to discuss the wildlife functions of PPR wetlands. Prairie pothole wetlands provide a diversity of animal species with a place to live. Many of these species are of economic importance (e.g., waterfowl, muskrats, mink, pheasants, deer), while other species provide links in the food chain (e.g., invertebrates which are used as food by waterfowl) to species of economic importance or are important for ecological, scientific, or aesthetic reasons (e.g., non-game birds). Published studies on the habitat requisites of many pothole wetland species are scarce. However, the body of literature on waterfowl in prairie pothole wetlands is large.

The importance of the PPR to breeding dabbling ducks (Anas spp.) cannot be overstated. Several scientific publications state that roughly 50 percent of the North American population of breeding dabbling ducks are produced in this region in an average year.

When the earliest of migrant ducks return to the region in spring (e.g., mallards—A. platyrhynchos, and pintails—A. acuta) the large semipermanent wetlands are typically still frozen. The first to warm-up and hence, thaw, are the small wetlands: temporary and seasonal wetlands. Temporary and seasonal wetlands provide space needed by breeding pairs so that interspecific encounters are kept to a minimum. When expressed on a density basis (breeding pairs/unit of surface area), tem-

porary and seasonal wetlands frequently receive higher duck use than other wetlands by some species of dabbling ducks.

Aside from pair isolation, seasonal wetlands provide a source of protein-rich invertebrate foods for breeding hens. The high use of seasonal wetlands attributed to the faster rate of warming in the spring (as opposed to semipermanent wetlands) thereby causing invertebrates to be more readily available. One study found that nesting mallard hens preferred temporary and seasonal wetlands and that individual hens used from 7 to 22 different basins (of all water regimes) in a season.

Semipermanent wetlands are also used extensively by breeding pairs of dabbling ducks but their use by diving ducks (Aythya spp.) is especially high. Breeding female diving ducks, like the dabblers, also consume high amounts of invertebrates during the breeding season; the invertebrates being obtained from the semipermanent wetlands. The later invertebrate availability, as compared to temporary and seasonal wetlands, in semipermanent wetlands coincides with the later breeding dates of the diving ducks. The dabbling ducks using seasonal and temporary wetland habitats switch to more use of semipermanent wetlands as the seasonal and temporary wetlands drawdown.

Juvenile waterfowl also require invertebrate protein sources. If broods hatch early, seasonal wetlands are preferentially used by mallard broods when available. When seasonal wetlands drawdown, hens move their broods to semipermanent wetlands. One study found that as many as 10 different basins were used by individual mallard broods, hence stressing the importance of the "wetland complex." They also found that hens were selecting for ponds containing high numbers of invertebrates for brood rearing sites.

A "wetland complex" is an area that contains many basins all in close proximity to one another. A good complex should have 1 or more semipermanent wetland to provide "guaranteed" brood-rearing habitat, and several temporary and seasonal wetlands for breeding pair space and feeding habitat and for brood habitat if water conditions permit. During dry years, when only the semipermanent wetlands are ponded, the duck production that occurs should provide for a source of returning birds to the area in the following year. When water conditions are good and temporary and seasonal wetlands are ponded, the number of ponds allows for not only homing hens and their mates to use the area, but also provides the space needed to accommodate pioneering birds and overall production should be increased. An analysis of mallard breeding numbers versus young produced in the PPR at 7 levels of abundance of wet ponds in May showed that the more ponds, the more young produced. This further demonstrates the importance of temporary and seasonal wetlands to waterfowl production as they are the greatest source of year to year variability in the number of wet ponds in spring. Large semipermanent wetlands may provide for some waterfowl production, but may not be able to provide as much space for conspecific breeding pair isolation as the same collective area of smaller wetland basins due to behavioral spacing mechanisms. Thus in areas where only semipermanent wetlands remain (the rest being drained) duck production is much reduced.

The exact impact of wetland drainage on the prairies to waterfowl populations is difficult to quantify. But several researchers have correlated wet pond numbers with duck populations and the correlations are obvious. When we have fewer wet ponds we have fewer ducks. Thus a logical conclusion that can be made is that if we ever get to the point where we have no wetlands, we will have no ducks. Thus, the decreasing populations of waterfowl in this century can be attributable to a large degree to prairie wetland drainage. I hope this rather brief discussion of PPR wetland functions has served to help enlighten you to some degree about these systems. In summary, prairie pothole wetlands are focal points in the hydrologic regime of the prairies. They store runoff water, thereby serving as potential floodwater storage reservoirs, and allow it to evapotranspire to the atmosphere or slowly seep into the groundwater. Leaving prairie pothole watersheds intact (i.e., not artificially draining them) will not prevent flooding in lower portions of the watersheds. However, artificially draining these watersheds may make flooding problems worse. Potholes can be either groundwater recharge sites, discharge sites, or groundwater flowthrough systems, and can temporarily change from one type to another depending on fluctuations in the watertable. Recharge to the groundwater in the surficial glacial deposits of the area is important to the maintenance of high water tables. High watertables provide water for livestock via dugouts and may be vitally important to the long-term water balance of the prairies by providing significant recharge to soil moisture. Along with water, nutrients are detained, or trapped, in potholes. Wildlife support is the best known function of prairie wetlands, especially in terms of waterfowl. These wetlands are critical to the maintenance of waterfowl popula-

tions on the continent. They also provide habitat for furbearers, resident game species, and many species of non-game wildlife. The expression of hydrologic and wildlife support functions is greatest when whole wetland complexes remain intact. It is the abundance of wetland basins distributed over the landscape that provides the most productive waterfowl breeding habitat, the most effective runoff water retention, and the best distribution of groundwater recharge.

In closing my testimony, I would like to thank the Subcommittee for allowing me the opportunity to express what I know about these wetlands. It has indeed been an honor to address you.

PREPARED STATEMENT OF MARK M. BRINSON

The statements and explanatory information wetlands provided below reflect current knowledge on their ecological functioning. I will place emphasis on wetlands in the southeastern U.S.A., especially nontidal, freshwater wetlands that are dominated by woody vegetation. For climatic and geomorphic reasons, these wetlands normally flood or have saturated soil during the cooler seasons of the year (2).

My comments fall into three categories and attempt to answer three general groups of questions: (a) What is the current condition-of wetlands in the Southeast? (b) How do the wetlands function, principally from the standpoint of water quality? and (c) What are the consequences of not maintaining these functions? Finally, I will briefly comment on the status of tools available to assess the functions of wetands, and point out some of the scientific issues that remain to be overcome. (Numbers in parentheses refer to endnotes beginning on page 4).

1. Virtually none of the wetlands remaining in the Southeast are a pristine, unaltered condition.

Implications

Wetlands of the Southeast have been heavily impacted during the post-colonial history of the country, and most extensively during the last half of the present century (3). Some wetlands have been permanently converted to other uses (cities, highways, industry), others are highly degraded and can be restored only at great expense (agriculture, residential areas, reservoirs), while the remaining ones have been altered in numerous ways (moderate drainage, stream channelization, intensive silviculture, changes in hydroperiod, extinction of species, etc.). The remainder of the comments refer largely to wetlands that have retained at least minimal capacities for carrying out their corresponding wetland functions.

2. The functions and ecological performance of wetlands depend largely on where they are located in the landscape relative to the sources of water flow.

Implications

Wetlands are unique landscape features because they represent predominately terrestrial settings and depositional environments located in an otherwise eroding landscape. The most effective among these for reducing non-point sources of nutrients and sediments reaching streams and rivers are located on headwater streams. This derives from the fact that the length of headwater streams exceeds that of other stream sizes (4); as such they interface extensively with uplands. Their capacity to trap sediments and nutrients generated from agricultural activities has been demonstrated conclusively in Maryland, North Carolina, and Georgia (5).

3. Alteration of drainage in wetlands normally circumvents the processes of sediment trapping and pollutant filtering. This switches the wetland into a reversal in function such that it releases rather than removes sediments and nutrients responsible for eutrophication.

Implications for water quality and contribution to greenhouse gases, depending on the wetland type:

a. *Water quality.*—Many riparian and floodplain areas of small streams have been channelized (a process that straightens, deepens, shortens, and widens the channel) and have received field ditches passing through the forested fringes of floodplains. These alterations not only interfere with the capacity for nutrient and sediment removal, but they often switch the wetland into a mode of nutrient and sediment production. Floodplains that have been accumulating sediment for thousands of years may begin to release them, thus contributing to water quality problems downstream (6).

b. *Greenhouse gases.*—For pocosin peatlands, installation of ditches to improve drainage exposes the organic soils to additional oxygen and subjects the land to ac-

celerated rates of organic matter oxidation and subsidence, including the very rapid losses during peat fires. The peat deposits in many pocosins represent thousands of years of accumulation, frequently ranging between 0.1 and 1.0 millimeters per year, indeed a slow process. Subsidence rates in drained peat lands most frequently occur in the range of 10 to 50 millimeters per year (7). The switch from a sink for carbon dioxide for the atmosphere to a source has significance for global climate change (8).

4. While it is clear that different types of wetlands have different functions, one of the handicaps of many assessment methods (9) is that they attempt to rank different wetland types that have fundamentally different functions.

Implications

a. Different wetland types should not be compared (ranked, indexed, scored, evaluated, etc.) with each other because they are unlikely to have equivalent functions to begin with. To the extent that they function differently, comparisons force the use of incongruent scales. This flaw makes such comparisons vulnerable to misinterpretation.

b. When different wetlands share functions (i.e., nutrient removal), more acres of the lower functioning wetland are needed to produce a given unit of function (10).

5. Available assessment technics (11) for determining the functions of wetlands are severely limited by (a) the scientific information available for different wetland types, (b) the resources to train people to be effective at functional assessment, and (c) the time available to apply assessment in the permitting arena.

Implications

While this is not a forum for discussing research funding, the fact remains that research support directed toward understanding the functions of wetlands has been minor relative to other programs on water quality, including but not limited to acid precipitation and the effects of point and non-point source pollution.

Wetland assessment requires a strong technical background, practical experience in field work, and sound judgment. Few training facilities are available and no reference or calibration wetlands have been set up as benchmarks for comparison.

Effective assessment requires sufficient time to gather data and assess the consequences of altering wetlands. Federal and state agencies that are responsible for carrying out the mandates of the Clean Water Act relative to wetland management are severely understaffed throughout the country.

ENDNOTES

(1) Currently I am Professor of Biology at East Carolina University in Greenville, North Carolina. During the 17 years since receiving my Ph.D., I have conducted ecological research on wetlands and estuaries, most extensively on cypress-tupelo floodplain swamps and brackish coastal marshes. My area of research deals with factors that control the ecological processes of plant production and the cycling of nutrients, both fundamental to the maintenance of integrity and functions of wetlands in the landscape. I am a member of the Society of Wetland Scientists (currently President), the Ecological Society of America, American Association for the Advancement of Science, the Estuarine Research Federation, Sigma XI the Scientific Research Society, as well as other professional groups. I am coeditor of a recent book on the ecology of forested wetlands worldwide (Lugo, A.E., M.M. Brinson, and S. Brown (editors). *Forested Wetlands.* Elsevier Scientific, Amsterdam. 527 pp.). I have provided technical input to programs on wetland research for the Fish and Wildlife Service, the Corps of Engineers, and the Environmental protection Agency during workshops which addressed the functions and values of wetland ecosystems, particularly the bottomland hardwood wetlands and pocosin wetlands.

(2) Because many of these wetlands do not flood deeply or do not remain flooded for most of the growing season, their ecological importance has come into question. Part of the reason for this misconception is that their vegetation and soils (usually lacking standing water) superficially resemble uplands. These intermittently flooded wetlands undergo drydown periods during the growing season as soils saturate during rainfall episodes and desaturate during intervening periods of high rates of water loss to the atmosphere. Ecosystem processes below the surface of the soil are very active where water tables fluctuate.

(3) During the 20 years since the mid 1950's in the lower 48 states, 9 million acres of wetlands were lost (an area equal to twice the size of New Jersey) to various uses, with agriculture accounting for 87% of the loss (Tiner, R.W., Jr. 1984. Wetlands of the United States: Current Status and Recent Trends. National Wetlands Inventory, Fish and Wildlife Service, USDI, Government Printing Office, Washington, D.C.). Of the southeastern states, Florida, Louisiana, North Carolina, and South Carolina

have approximately 5 million acres or more (Dahl, T.E. 1990. Wetlands Losses in the United States 1780's to 1980's. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. 21 pp.). Losses of bottomland hardwood forest to cropland has been particularly high in the lower Mississippi alluvial plain since 1950 (Turner, R.E., S.W. Forsythe, and N.J. Craig. 1981. Bottomland hardwood forest land resources of southeastern United States. In J.R. Clark and J. Benforado (editors). Wetlands of Bottomland Hardwood Forests. Elsevier Scientific Publishing, New York). Pocosins once covered nearly 1 million hectares in North Carolina (1 hectare equals 2.47 acres). Drainage and other uses have reduced them to 281,000 hectares by 1980 (Richardson, C.J. 1983. Pocosins: Vanishing wastelands or valuable wetlands? BioScience 33:626–633.)

Several efforts to estimate losses have been criticized because they used maps of hydric soils produced by the Soil Conservation Service as the estimate of the original extent of wetland coverage. The approach is supported, however, by studies of geographically diverse sites that examined the correspondence between soil type and vegetation cover. The results indicated that soils serve as a reasonably reliable predictor of whether vegetation is hydric or non-hydric (Scott, M.L., W.L. Slauson, C.A. Segelquist, and G.T. Auble. 1989. Correspondence between vegetation and soils in wetlands and nearby uplands. Wetlands 9:41–60.). Only 10% of the hydric soils sampled supported upland plant communities, and only 15% of the non-hydric soils supported wetland communities.

(4) Page 142 of Leopold, L.B., M.G. Wolman, and J.P. Miller. 1964. Fluvial Processes in Geomorphology. W.H. Freeman and Co., San Francisco.

(5) Data are available for a coastal plain stream in Maryland where there is extensive agricultural activity (Peterjohn, W.T. and D.L. Correll. 1984. Nutrient dynamics in an agricultural watershed: Observations on the role of a riparian forest. Ecology 65:1466–1475). The North Carolina study reported that of the total delivery of sediment from cultivated fields, 84 to 90 percent is removed and remains in the watershed. The authors recommend that "natural vegetation should be left in drainage areas such as intermittent streams and flood plain swamps to promote stability of the channel and to maintain the potential for filtering of sediment and sediment associated nutrients" (Cooper, J.R., J.W. Gilliam, R.B. Daniels, and W.P. Robarge. 1987. Riparian areas as filters for agricultural sediment. Soils Science Society of America Journal 51:416–420). Further results from the North Carolina study indicated that phosphorus removal is also effective. Of the total phosphorus removed over the past 20 years from the watershed largely under cultivation, 50 percent is removed in riparian areas (identified as forest edges, ephemeral streams, flood plains of intermittent streams, and flood plain swamps) (Cooper, J.R. and J.W. Gilliam. 1987. Phosphorus redistribution from cultivated fields into riparian areas. Soils Science Society of America Journal 51:1600–1604). Studies on agricultural watersheds in Georgia further support that this is a widespread phenomenon (Lowrance, R.R., R.L. Todd, and L.E. Asmussen. 1984. Nutrient cycling in an agricultural watershed: I. Phreatic movement. Journal of Environmental Quality 13:22–27; Lowrance, R., R. Todd, J. Fail, O. Hendrickson, R. Leonard, and L. Asmussen. 1984. Riparian forests as nutrient filters in agricultural watersheds. BioScience 34:374–377).

(6) The concept of reversal in function can be put into perspective for the Nation as a whole. Wetlands occupy approximately 5 percent of the land surface of the lower 48 states. The remaining 95 percent is upland, which has erosion rates ranging to quite low under most natural conditions and to quite high in areas of intense human activity (building construction sites are among the worst). Floodplain wetlands are intrinsically depositional areas, just the opposite of uplands. Although they cannot possibly trap all of the sediment and remove all of the nutrients that are delivered to them, removal efficiencies of 80 to 90 percent are common. Hence, floodplain wetlands, small relative to the surrounding upland landscape, accumulate soil rather than loose it. (This is why bottomland areas had such highly fertile soils.) When these wetlands undergo hydrologic alterations, such as stream channelization, the floodplain wetlands usually undergo a reversal in function such that they export sediments downstream rather than retain them. The rate of loss is invariably more rapid than the rate of accumulation.

(7) Summarized in Brinson, M.N. 1988. Strategies for assessing the cumulative effects of wetland alteration on water quality. Environmental Management 12:655–662.

(8) Draining of these soils and imposing other types of disturbance reverses the process of accumulation. From a global perspective, wetlands so disturbed contribute to the atmospheric loading of carbon dioxide, and even if pocosin vegetation were replaced by fast-growing pine plantations, they would likely continue to be a net source of carbon dioxide. From the standpoint of atmospheric loading, this is analo-

gous to converting old growth forests of the Pacific Northwest to plantations (Harmon, M.E., W.K. Ferrell, and J.F. Franklin. 1990. Effects of carbon storage of conversion of old-growth forests to young forests. Science 247:699–704) and to cutting and conversion of tropical rainforest to annual crops and pasture. The contribution to greenhouse gases is a good example of what is meant in the guidelines for cumulative effects, i.e., "the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time (40 CFR 1508.7).

(9) There is still some confusion between the terms "functions" and "values." Some use the words interchangeably. A useful distinction, however, is to first recognize processes that occur in wetlands (plant production, bacterial decomposition, nutrient cycling, etc.) which contribute to functions in the landscape that have ecological significance (i.e., trapping nutrients and sediments, supporting bird and mammal populations, etc.). From these functions, one can derive values that have social significance. Because values, especially monetary ones, can vary geographically and over time (wetlands were once considered to be worthless areas of pestilence), there should be a strong distinction between functions and values in assessment techniques.

(10) The concept of producing a unit of function might seem antithetical to prevailing approaches to land use and land value. However, it conforms to the reality of how wetlands function. The topic of values assessment for wetlands is well beyond the scope of this testimony. The subject has been treated elsewhere (Whigham, D. and M.N. Brinson. 1990. Wetland value impacts. In B.C. Patten et al. (editors). Wetlands and shallow Continental Water Bodies, Volume 1. SPB Academic Publishing bv, The Hague; Lugo, A.E. and M.N. Brinson. 1978. calculations of the value of salt water wetlands. In P.E. Greeson et al. (editors). Wetland Functions and Values: The State of Our Understanding. American Water Resources Association, Minneapolis).

(11) The most widely used assessment technique was first published in 1983 (Adamus, P.R. and L.T. Stockwell. 1983. A Method for Wetland Functional Assessment: Volume I. Report No. FHWA-IP-82-24, Office of Research and Development, Federal Highway Administration, Washington, D.C.) and has undergone revision to the currently used "Wetland Evaluation Technique (WET)" (Adamus, P.R., E.J. Clairain, Jr., R.D. Smith, and R.E. Young. 1987. Wetland Evaluation Technique (WET). Volume II: Methodology. Environmental Laboratory, U.S. Army Corps of Engineers, Vicksburg, Miss. 206 pp.). Briefly, this technique requires data collected from a particular project site (usually being evaluated for a section 404 permit), the data are used to answer a series of questions, and the answers are used in an interpretation key to determine the most likely functions of a wetland and their significance. These functions tend to fall into three categories: habitat (for fish, waterfowl, furbearers, etc.); water quality maintenance as a result of nutrient, sediment and contaminant removal; and hydrologic processes including flood hazard reduction. Regulatory agencies of several states have developed their own modification of the WET template to better accommodate their geographically restricted situation. One of the tradeoffs in using WET is that it sacrifices sensitivity for discriminating among the functions of wetlands in the process of making the technique robust enough to assess all wetlands nationwide.

The Waterways Experiment Station (WES) of the Army Corps of Engineers recently (March 1991) held a workshop in Stone Mountain, Georgia, to consider another generation of assessment methods. The Wetland Program at WES has begun an effort to develop "assessment models" for many wetland functions. Another widely used method is the Habitat Evaluation Procedure (HEP) of the Fish and Wildlife Service. HEP is not specific to wetlands, however. Additional methods are being developed in states and a number have been described in the literature (Karr, J.R. 1991. Biological integrity: A long-neglected aspect of water resource management. Ecological Applications 1:66–84) but none of these are as widely used as WET. For a comprehensive compilation of methods, see U.S. Environmental Protection Agency. 1984. Literature Review of Wetland Evaluation Methodologies. Technical Report, EPA Region 5, Chicago, IL 120 pp.

Weaknesses that are common to all assessment techniques include the lack of scientific information on the functions of wetlands, uncertainty about the ecological significance of the functions, and the extent to which society benefits or is otherwise affected by these functions. The process could benefit greatly by the establishment of a nationwide network of "calibration wetlands" as focal points of research into better assessment indicators and as sites for training agency personnel that conduct

assessments. Wetlands in such a network would also serve as examples toward which wetland construction and restoration efforts should be directed.

On a large scale, cumulative impact assessment has been developed for bottomland hardwood forests through a series of workshops held between 1984 and 1986. The results from these workshops have been published (Gosselink, J.G. and L.C. Lee. 1989. Cumulative impact assessment in bottomland hardwood forests. Wetlands 9:89–174; Gosselink, J.G., L.C. Lee, and T.A. Muir. 1990. Ecological Processes and Cumulative Impacts. Lewis Publishers, Chelsea, Michigan. 708 pp.), but, to my knowledge, the approach has not been applied widely. Work is underway by the EPA Wetlands Program to further develop techniques for wetland assessment at the landscape level, with the goal of addressing the issue of cumulative impacts to wetlands resulting from incremental losses of area or function over time. The EMAP-Wetlands program in EPA is initiating a pilot project to test techniques for assessing long-term trends in wetland "health," in contrast to the site specific effects of a potential project on a permitted area.

PREPARED STATEMENT OF DR. JOSEPH S. LARSON

Mr. Chairman, I am pleased to have the opportunity to share with you an overview of what wetland scientists know about the saturated wetlands of the Northeastern United States and the use of wetland ranking. I have been involved in wetland research, policy development and formulation of State wetland regulations in the Northeast for over 20 years. I chair the National Wetlands Technical Council and the U.S. National Ramsar Committee that advise public agencies on wetland research and on matters related to U.S. obligations under the Convention on Wetlands of International Importance (Ramsar). For several years I have been an advisor to the World Conservation Union (IUCN) on wetlands and I also served as a science and policy advisor to the National Wetlands Policy Forum.

Saturated forested, vernal pool, bog and wet meadow wetlands are a major and important component of the freshwater wetlands of the Northeastern United States. They have important implications for public health, welfare and safety. I am pleased that your Subcommittee has decided to give these issues careful consideration.

SATURATED WETLANDS OF THE NORTHEASTERN UNITED STATES

What are saturated wetlands?

Saturated wetlands in the Northeast are largely forested "swamps", forested floodplains, wet meadows, bogs and vernal pools. Many of these, especially forested wetlands, have standing water in them only during part of the year, typically winter and early spring. Vernal pools often occur within forests and typically dry up by mid summer. Bogs often have open pools of water year-round. Wet meadows often have water on the surface long enough to discourage tree growth. All of these wetlands occur on hydric mineral or organic soils that are saturated with water near the surface for all or a significant part of the year.

Extent

In New England hydric soils comprise 14 percent of Connecticut, 33 percent of Maine, 17 of Massachusetts, 17 percent of New Hampshire, 17 percent of Rhode Island and 25 percent of Vermont. But a major portion, possibly as much as 50 percent in Massachusetts alone, have been drained for agriculture and other uses, and wetlands now comprise significantly less area in each State. Forested wetlands alone comprise well over one half of all the remaining freshwater wetlands in the Northeast. In northern New York and New England the proportion is much higher, but even in the densely populated southern part of our region fully one half of the freshwater wetlands are forested. Adding in the wet meadows, non-forested bogs and vernal pools, saturated wetlands may comprise as much as 70 percent of all Northeastern freshwater wetlands.

FUNCTIONS

Wildlife Habitat

Forested wetlands are highly significant migratory song bird breeding habitat. Many of the same species whose winter habitat is threatened by cutting and burning tropical forests use the forested wetlands of North America as their summer

breeding grounds. As many as 46 different species breed in forested wetlands of west-central Massachusetts. The total number of song birds, as well as number of bird species, nesting in a given area tends to be higher in forested wetlands versus upland forest.

Four species of migratory waterfowl use forested wetlands as breeding and brood rearing habitat: black duck, mallard, wood duck and hooded merganser. In severe cold weather black ducks that winter in the coastal marshes of New Jersey use inland flooded forested wetlands as shelter. Black duck populations have experienced a recent dramatic decline in numbers.

Vernal pools are essential breeding habitat for many of the amphibians of the Northeast. These species require pools that dry up and are thus free from fish predators for egg survival. They cannot survive without vernal pools, and many of these are rare, endangered, or threatened species. Several reptile species make important use of vernal pools as well.

Many mammal species are common in forested wetlands, including small mammals that provide an important food base for carnivorous mammals, hawks and owls. Beavers depend on forested wetlands for creating their habitat and for winter food. Recent studies in Massachusetts have shown that black bears spend over 60 percent of their time during the spring in forested wetlands feeding on herbaceous plants and berries. White-tailed deer make extensive use of forested wetlands, and in the northern part of our region many of the essential deer wintering yards are forested white cedar or black spruce wetlands.

Because bogs are highly stressed communities in terms of surface temperature extremes and specialized water regime, they support very unique plant and animal communities. Plants that grow in bogs have special physical and physiological adaptations that allow them to survive where other species do not. They cannot survive on other sites in competition with upland plants. The diversity of birds and mammals found in bogs may actually be higher than in surrounding uplands because of the higher diversity of vegetation on peatlands. A number of invertebrates endemic to bogs and peatlands are likely to be relicts of an earlier Ice Age. From a scientific aspect these bogs are especially important for preservation of genetic material, research, and education.

Flood Control and Surface Water Quality

Large forested wetlands and wet meadows on floodplains along the middle reaches of river systems in the Northeast play an important role in detaining flood waters and maintaining water quality. They act as natural water detention basins during the winter, annual spring flooding and for floods at any other time of the year. This role reduces the height of flood crests and property damage downstream. Loss of these wetlands would likely result in demands from downstream communities for construction of flood control dikes and dams.

During floods these wetlands also become sites where sediment settles out of surface water. This process maintains downstream surface water quality not only by sediment removal but by removal of pollutants like bacteria and heavy metals and nutrients like phosporous that are attached or bound to sediment particles. Loss of this function would reduce suface water quality, fish habitat quality and increase the costs of water treatment for municipal and industrial uses.

Groundwater Implications

Saturated wetlands in the Northeast are most frequently sites where groundwater discharges to the surface like large diffuse springs. Some of these are headwater sources for streams. Many of these discharge to the surface only during spring and early summer. During the dry parts of the year these sites have the potential for recharging back into subsurface aquifers. A few are sites where recharge to groundwater occurs year-round. In these instances of periodic or constant recharge, human development of the surface saturated wetland has the potential for adverse effects on the subsurface aquifer water quality.

In Massachusetts alone, 60 municipalities draw their drinking water from subsurface wells drilled in or adjacent to large forested wetlands. The precise relationship of each of these wetlands to the aquifer from which the public drinking water is pumped is complex, dependent on site-specific surficial geology, and it is not possible to generalize for all sites. But these saturated forested wetlands, and others that have may be capable of being developed for future wells should not be materially changed without intensive examination of the potential for adverse impacts on the subsurface aquifer.

AGRICULTURAL LIMITATIONS IN SATURATED WETLANDS

Sophisticated research is not needed to show that saturated wetlands have very major limitations to agriculture and forestry. Similarly, there is ready evidence that they present high public risks and costs if developed for housing, roads, industry and many other uses.

Agricultural and Forestry Limitations

In introductory agriculture and forestry courses students learn that you don't try to grow row crops on the soils that occur in Northeastern saturated wetlands and they do not produce good quality timber. USDA Soil Conservation Service county soil manuals warn that these hydric mineral and organic soils usually have severe limitations for woodland management and crop farming.

The limitations are related to the fact that these soils are saturated in the spring and early summer. They are difficult to prepare for row crops and give significantly reduced yields compared to well-drained soils. In some cases drainage will improve their use of agriculture, but in the Northeast virtually all the hydric soils that respond well to drainage were drained decades ago. Those that remain support saturated wet meadows and forested wetlands where drainage failed or was physically impractical. In some cases they will provide natural hay land and pasture if care is taken not to overstock with grazing animals. Hay and pasture are uses that will not have major adverse impacts on the hydologic functions of wetlands.

Hydric soils limit the use of forest harvesting equipment to the period of frozen ground. The quality of forested wetland trees for timber is low due to disease and poor growth related to poor oxygenation in the soils. Large trees in wetlands are subject to windthrow because they develop shallow root systems in saturated soils. Careful forest management for fuel and pulp wood will not impair the hydrologic functions of wetlands. Pulpwood harvesting in coniferous wetlands that serve as deer yards can have a major adverse impact on white-tailed deer populations.

COSTS AND PUBLIC HEALTH RISKS OF DEVELOPING SATURATED WETLANDS

The hydric soils of saturated wetlands pose especially important costs and risks that often result in major financial costs to municipalities. These risks are well documented in USDA county soil manuals and in the experience of many Northeastern city and town health boards.

The seasonal rise in groundwater, or saturation due to an impervious subsurface layer that prevents downward movement of water from spring snow melt, leads to flooded basements in homes and failed on-site sewage disposal systems. Both conditions present public health hazards. Municipal authorities are pressed to pump out cellars, often at public expense. Continued failure of on-site septic systems can only be remedied by major installation of sewer lines and treatment plants at taxpayer expense. Placement of sewer lines through saturated soils poses a risk of groundwater infiltration to the lines that involves much more expensive pipe installation and a perpetual potential for reduced treatment plant effectiveness.

The significance of development risk in saturated wetlands in the Northeast is high. Virtually all of the northern part of our region and a very significant portion of the middle and southern section is not served by municipal water and sewer systems. Much new year-round and vacation residential development occurs on sites where each home is dependent on drinking water from a drilled well on the lot and uses the same lot for a septic disposal system. When the septic system fails due to seasonal saturation the water supply on that lot and on adjacent lots is put at risk. Too often entire subdivisions experience failure some years after the developer has finished and the cost of extending or providing new sewer systems becomes a city or town taxpayer expense.

The costs of extending systems or building new systems, even in prosperous times, are such that many residential developments will continue to depend upon on-site wells and sewage disposal. Once inappropriate development occurs on saturated wetland soils there is no pragmatic resolution of the problem that does not entail major taxpayer expense. As a matter of sound public health policy and fiscal prudence, development should be excluded from the saturated wetlands of the Northeast.

THE USE OF WETLAND VALUE RANKING

What is wetland ranking?

For a number of years wetland scientists have been developing techniques by which management and regulatory agencies can better estimate which functions are

present in a given wetland. Several assessment models have been developed for use within some regions of the United States. The most widely known system is the Wetland Assessment Technique (WET), now supported by the U.S. Army Corps of Engineers.

The objective of these systems is to give agencies an improved estimate or prediction of which functions are likely to be operative in a wetland. They are planning tools to be used when little site-specific information is available on wetlands. They do not provide quantitative measures of functions. For example, if a transportation corridor for a new highway has 5 potential road alignments, all of which will cross wetlands, the WET system will provide a rapid estimate of which combination of wetland crossings are likely to affect a given function.

Use and mis-use of ranking

Properly used, these models give an agency an early warning of the issues that are likely to arise in a proposed project or within a particular group of wetlands. They can provide a basis for advanced public designation of wetlands of critical concern that will require greater scrutiny before an alteration permit will be issued. They can assist in integrating wetland protection into water quality and flood protection programs.

Unfortunately, wetland assessment models are being improperly used, even by some offices of the Corps of Engineers, to measure the effect of impacts, to judge whether a constructed wetland is an adequate replacement for a filled natural site or to develop design criteria for constructing replacement wetlands. Assessment models do not provide the quantitative information needed to make these kinds of regulatory decisions. Site-specific information is needed to adequately make final decisions.

National Wetland Inventory maps may be misused

Of major concern to scientists is the current interest in using the models in conjunction with National Wetland Inventory (NWI) maps to put mapped wetlands in different "value" classes. The models only express a probability of a function being present, not a value estimate. NWI maps label wetlands in relation to their position on the landscape and their major vegetation. This information may be useful in making preliminary assessment of certain functions, like flood control and habitat for waterfowl. But they do not indicate that wetland with the same names have the same functions, or value. The aerial photo interpretation that is the basis for these maps cannot provide that information. On-site examination is needed to assess whether the wetland actually functions, and at what level, to provide water quality maintenance, groundwater recharge, habitat for most wildlife, etc.

From the beginning of the NWI mapping program, concern has been widely raised that they will be used to designate wetlands for regulation. Scientists have made an effective and strong case that the maps are resource inventory tools that were never intended to be used to designate legal wetland boundaries for jurisdictional purposes. The National Wetlands Policy Forum has specifically warned against this improper use. Using these maps to put wetlands into value classes has as little scientific merit as using them to designate areas to be regulated.

A valid approach to wetland value assessment is to use the assessment models as preliminary screening devices to quickly establish the potential for some functions. This needs to be followed by on-site data appropriate for that site. Only then will there be a basis for making effective regulatory decisions that protect the public interest.

PREPARED STATEMENT OF MARY E. KENTULA

Good morning, Mr. Chairman and members of the subcommittee. I am Mary E. Kentula, a research ecologist with EPA's Research and Development Laboratory at Corvallis, OR. I am pleased to come before you to speak about wetland creation and restoration. As you know, wetlands are important features of the landscape, often acting to improve water quality, store flood waters, or provide vital habitat. Therefore, the ability to create and restore wetlands is crucial to maintaining the quality and quantity of the wet land resource.

The most current assessment of the ability to create and restore wetlands was recently completed and published as part of EPA's Wetlands Research Program. That document, Wetland Creation and Restoration: The Status of the Science, reports the status of wetland creation and restoration by region and wetland type and discusses

wetland creation and restoration in relation to topics in ecology and resource management such as ecological succession and waterfowl management. I will begin my discussion by briefly summarizing the major findings of the report. More detail is presented in the Executive Summary from the document which was submitted to you with my prepared statement.

The first general conclusion reached in the report was that practical experience and the available scientific knowledge on restoration and creation are limited for most types of wetlands. The amount of information also varies regionally and with the wetland function of interest. It is probably impossible to exactly replicate any given wetland through creation or restoration since natural systems are very complex and highly variable. The subtle relationships of water, soils, vegetation, animal life, and nutrients which may have developed over thousands of years in natural systems have not been totally identified, let alone studied in the context of restoration or creation. Nevertheless, experience to date suggests that some types of wetlands can be approximated and certain wetland functions can be restored, created, or enhanced. For example, it is often possible to restore or create a wetland with vegetation resembling that of a natural wetland. This does not necessarily mean, however, that it will have habitat or other values equaling those of a natural wetland or that such a wetland will be self-sustaining, as are many natural wetlands.

The amount of information available on wetland creation and restoration varies by wetland type and the region of the country being considered. The most is known about the creation and restoration of the smooth cordgrass (Spartina alterniflora) marshes of the low intertidal regions of the Atlantic coast. However, much less success has been achieved with the high intertidal marshes and the seagrasses that occur in the same region. Even less is known about creating and restoring wetlands on the Gulf and Pacific coasts. By far, however, the least is known about restoring and creating inland wetlands.

The information available also varies by the wetland function of interest. The most is known about creating and restoring the flood control and waterfowl production functions of wetlands. The least is known about some of the water quality improvement functions and the groundwater recharge and discharge functions.

The second general conclusion reached in the report is that most wetland restoration and creation projects do not have specified goals, and this complicates efforts to evaluate "success". Project goals seldom have been specified, even in cases where wetlands have been intentionally restored or created. Partial failures are common. Common problems include: lack of scientific knowledge; lack of expertise in project design; lack of project supervision; improper site conditions; and failure to protect projects from impacts such as grazing, sedimentation, and toxics. Success often depends on expertise in project design and on careful project supervision. It also depends upon the long term ability to manage, protect, and manipulate the wetlands and adjacent areas. Restored or created wetlands should be designed as self sustaining or self managing systems unless a project sponsor clearly has the incentive and capability for long term management.

The third general conclusion reached in the report was that monitoring of wetland restoration and creation projects has been uncommon. Most investigations of wetland creation and restoration have been short term case studies with little quantitative data and no comparisons with natural wetlands. Those investigations that have rated the success of wetland creation projects most often do so on the basis of compliance with permit requirements. For example, whether or not the project has been constructed, or whether or not vegetation has become established. More detailed and longer term monitoring is required to determine if wetland functions are being replaced over the long term.

A number of studies have been implemented by EPA's Wetlands Research Program to meet the information needs identified in the status report. I will briefly describe some of the results of EPA's studies. In addition, my written testimony includes the abstracts from a session on wetland creation and restoration that I organized for the 1990 meeting of the Society of Wetland Scientists. These abstracts represent some of the most current work in the field.

Results from EPA studies too recent to be included in the status report show that many of the differences between created and natural freshwater systems can be related to the relative differences in the ages of the sites. For example, created systems have less soil organic matter and less plant cover, but have a higher plant diversity. Over time one would expect the organic matter to increase, plant cover to increase, and diversity to decrease as competition for space and resources increases. However, one potentially important difference between the created and natural systems is that they differ structurally and hydrologically. Created systems have significantly more open water than similar natural systems in the regions studied.

This means that the wetlands being created are different from wetlands found in the region and that changes in the relative proportions of wetland types in an area are occurring due to compensatory mitigation under Clean Water Act Section 404. Results from one study showed that monthly water levels in created systems were less variable than those of nearby natural systems. This difference will undoubtedly affect the structure and function of the created wetlands, since hydrology is the key to wetland structure and function. In addition, the setting of the wetland appears to influence the structure and function of the site. Wetlands in an urban setting differ from wetlands in a rural setting.

EPA's Wetlands Research Program also examined permit specifications, construction plans, and field measurements to evaluate project design and construction. I will briefly summarize the results from a study in Oregon. Data analysis for similar studies in Florida and Connecticut is now being completed. Results of EPA's wetland study in Oregon indicate that none of the wetlands evaluated were constructed as either designed or permitted. The study focused on a population of 11 mitigation projects created in Portland, OR, between 1980–1986. The projects ranged from six months to almost seven years in age. Data on planned and existing hydrology, wetland area, wetland shape, slopes of banks, and vegetation were collected for each site. The hydrologic design could not be evaluated since the information in the permit files was inadequate. There was a cumulative loss of 3.6 acres, or 29 percent from the 12.6 acres that was to be created. For 45 percent of the sites (5/11) the predominant slopes to be built and as-built were steeper than the 5:1 maximum recommended in the literature. The steep slopes caused a large proportion of the sites to be dominated by open water rather than vegetation. Vegetation planned to be planted did not occur on the sites; no more than 7 percent of the species that occurred on the site were planned. In summary, because the knowledge on wetland creation and restoration is fragmented and incomplete wetland restoration and creation proposals should be reviewed with care. This is especially true when the restoration or creation is proposed in exchange for the destruction of an existing wetland. In evaluating proposals involving the destruction of an existing wetland, both the importance of the ecological role of the wetland locally and in the surrounding landscape and the probability that the creation or restoration project will succeed should be taken into consideration. The amount of risk associated with the creation or restoration project should be reflected in the stringency of design requirements, compensation area ratios, and performance criteria. In general, restoration should be favored over creation. Restoration of a damaged or destroyed wetland will have a greater chance of recreating the range of prior wetland functions including critical habitat and of persisting over the long term.

Mr. Chairman, this completes my statement. I will be pleased to respond to any questions you may have.

PREPARED STATEMENT OF DR. JOY B. ZEDLER

This testimony responds to the general question: Do man-made wetlands replace natural wetlands? The answer is based on a 20-year research program that has sought to understand southern California coastal salt marshes, including the work of many associates and graduate students. The California Sea Grant College funded much of our research and recently published our manual of how to compare the functions of natural and restored wetlands (PERL 1990).

San Diego Bay's man-made wetlands include eight small islands at the Sweetwater Marsh National Wildlife Refuge and a 55-acre dredge spoil island known as the Chula Vista Wildlife Reserve. These islands were built over 6 years ago and comprise two mitigation projects. They were constructed to compensate for the loss of natural salt marsh habitat.

1. Do the man-made marshes support the desired native species? —No.

Tall cordgrass vegetation, needed by clapper rails for nesting and cover, is rare, although short plants are present on all the islands.

The Light-footed Clapper Rail, an endangered bird for which these islands were designed, does not use them.

Marsh invertebrates, which serve as food for birds and other animals, are not very abundant. The islands studied by Rutherford (1989) had only a third as many of these food items as in the natural reference wetland. Lower invertebrate densities were also found in cordgrass marshes built in North Carolina (Sacco 1989)

Predatory insects that control herbivory are too rare. The dredge spoil island failed to attract a native beetle that feeds on scale insects. About four years after the marsh was constructed, the scale insect population grew to pest proportions and

substantially damaged the cordgrass. Insect diversity was low overall; Johnson (1991) found only 4 orders of insects on the dredge spoil island, while the natural marsh supported 11 orders.

An endangered annual plant, the salt marsh bird's beak is absent except at one small island where we transplanted it. It is unlikely to persist at that site.

In summary, several critical species are not sustained by San Diego Bay's man-made wetlands.

2. Do the man-made marshes function as well as natural wetlands? —No.

Pollination is impaired. The endangered plant is pollinated by small ground-dwelling bees, which live in upland habitats. The man-made islands lack the habitat that supports pollinators. Food chain support appears to be impaired. Rails and other carnivores need invertebrate foods; carnivores are limited by low densities of invertebrate prey; the invertebrates, in turn, may be limited by inadequate plant foods.

High-tide refuges are lacking. The paucity of tall plants makes it difficult for beetles to escape inundation by high tides. The lack of vegetation on the tops of the man-made islands means there is no cover during high water. The lack of land connections between the man-made islands and uplands, makes it harder for animals to move to high ground.

Predator protection for birds is inadequate. The rails need tall cordgrass for protective cover. Short plants expose them to predators, especially at high tide.

Nesting habitat is inadequate. Rails build their nests in tall cordgrass, which protects eggs and chicks during high tide. Short vegetation would expose nests, which float as the water rises.

Plant growth is impaired. Cordgrass needs more nitrogen to grow tall enough to provide cover at high tide. To supply more nitrogen, the site needs organic substrates, both to release bound nitrogen and to fuel the nitrogen-fixing microbes.

We summarized the shortcomings of the man-made marsh islands using 11 data sets that were collected when the site was 4–5 years old. We concluded that the man-made marsh was less than 60 percent functionally equivalent to the natural reference marsh (PERL 1990).

3. Are these man-made marshes likely to improve and persist? —No.

They can't mature fast enough. A natural marsh accumulates organic, nutrient-rich soils over long periods of time, perhaps centuries. We failed to see an increase in nitrogen status our two-year study (Langis *et al.* 1991). Similar problems have been documented for salt marshes in North Carolina (Craft 1986, 1988) and Texas (Lindau and Hossner 1981).

They are not self-maintaining. The large dredge spoil island is held in place by a berm that is eroding; without repairs it won't persist. The smaller islands need to be fertilized. We can add organic matter and nitrogen to improve plant growth, but we don't know how to make the benefits persist. The flowers of the endangered annual plant need to be pollinated, unless it can produce seeds, the population won't persist.

The man-made sites are too easily invaded by exotics. Invasive species, such as Japanese mussels, establish readily on disturbed substrates; they may repel natives and further slow restoration of the native marsh fauna. Rutherford (1989) found 7 times more Japanese mussels at the man-made islands than at the natural marsh.

They will succumb to accelerated sea level rise, which will result from global warming. There is no space for these urban salt marshes to migrate inland and, for island marshes, there is no mechanism to maintain them in place.

The man-made marshes are too small and too isolated. Island biogeography studies demonstrate that larger, connected habitats support greater biodiversity.

In summary, they are "wetland gardens" that need constant maintenance.

California's wetlands face a biodiversity crisis. The State has lost 91 percent of its historic wetland acreage (Dahl 1990). Less habitat means fewer species. Dr. E. O. Wilson (1989) of Harvard University predicts that a 90 percent loss in habitat area would force half the species to extinction. Our research on southern California wetlands shows that we cannot yet compensate for lost wetland habitat. If decision-makers continue to permit wetland habitat destruction on the promise that damages can he mitigated, it will only heighten the biodiversity crisis.

TECHNICAL SUPPORT FOR THIS TESTIMONY

These mitigation sites have taught us a great deal about how natural wetlands function—it's much easier to identify the role of a species or environmental factor when it's missing than when it's present. We have also learned that wetland restoration and creation are very difficult, that salt marsh ecosystems develop slowly,

and that some problems (e.g., insect outbreaks) may not occur until years after the project is in place.

The studies at Sweetwater Marsh National Wildlife Refuge (NWF) have passed peer review, as evidenced by the publication of Langis *et al.* (1991) and Zedler (in press). Four M.S. theses (Cantilli 1989, Rutherford 1989, Swift 1988, Zalejko 1989) concerning the manmade marsh have been reviewed and accepted by the SDSU eulogy faculty. The work has been endorsed by NOAA's Coastal Ocean Program, which supported publication of the Assessment Manual (PERL 1990). The studies of the dredge spoil island have been funded and accepted by the Port of San Diego (unpub. reports by J. Zedler, C. Nordby, K. Williams, and T. Winfield). One M.S. thesis (Johnson 1991) has been reviewed and accepted by the SDSU ecology faculty.

We summarized eleven detailed data sets from the Sweetwater Marsh NWF, expressing each data summary for the man-made marsh as a percent of that at the natural salt marsh. Soil and plant data were taken from Langis *et al.* (1991) except for plant heights (unpub. PERL data). Epibenthic invertebrate data were from Rutherford (1989). The sediments had 51 percent as much organic matter, 45 percent as much inorganic nitrogen, 52 percent as much total nitrogen. There was only 17 percent as much inorganic nitrogen in the soil pore water—this nitrogen is probably what is most available for plant uptake. Microbes on the marsh surface fixed 51 percent as much nitrogen, while thus in the root zone fixed 110 percent (note that fixation turns on when there is little inorganic nitrogen in the soil). Plant biomass was 42 percent as high; leaves had 84 percent of the nitrogen content; and plants were 65 percent as tall. Epibenthic invertebrates were only 36 percent as numerous, although the species lists were 78 percent similar. The average (<60 percent) should be interpreted as a maximum functional equivalency rating, since we sampled areas of better cordgrass growth in the mitigation marsh and avoided the bare patches. Tidal elevation was held constant for both the man-made and natural wetlands.

These differences in the functioning of the mitigation and natural marshes are ecologically understandable, and our research suggests why the man-made marsh is functionally impaired. Compared to natural marshes, the substrate is sandier and has little organic matter; this is probably because excavation uncovered alluvial outwash from Sweetwater River, rather than historic marsh substrates. With less soil organic matter, there is less nitrogen for microbes to mineralize and little energy for nitrogen fixation. With lower nitrogen inputs, plant growth is limited and foliar nitrogen is lower. With lower plant production and lower quality plant biomass, the detrital food chain may be impaired, as indicated by fewer invertebrates in the epibenthos. Finally, with less food and a shorter plant canopy, the site is not yet suitable for residency by the Light-footed Clapper Rail.

Tests of the above cause-effect model are underway, and preliminary findings support the above statements. We added organic matter and nitrogen to experimental plots in a new 17-acre mitigation marsh at San Diego Bay. Preliminary results (Zedler and Langis, unpub. report to the California Sea Grant College, 1990) support the hypotheses that cordgrass growth is nitrogen-limited and that soil amendments can accelerate vegetation development. It is too soon, however, to know if one-time applications of nitrogen or nutrient-rich organic matter can sustain greater plant growth.

RESEARCH NEEDS

There is much more to be learned. Several problems that occurred at the man-made marshes need further study. Methods of improving these wetlands need to be developed. Management actions will follow from new findings and improved restoration technology. Evidence supports each of the following hypotheses (in bold), but greater certainty will come with repeated tests.

Exotic species are more likely to invade man-made habitats than natural wetlands. *Evidence:* An exotic mussel, Muscinlista senhousia, was attracted to the unvegetated substrates. This invasive mussel builds a dense mat of byssal threads that may make it difficult for the larvae of native species to settle and grow. Rutherford trapped 63 individuals of this species, 55 of which were in the constructed marsh. The native marsh may have built-in resistance mechanisms that reduce chances for exotic species invasions. *Research needs:* We need to understand what allows various exotic species to establish in man-made marshes and to identify the mechanisms of resilience that are inherent in natural marshes. *Management needs:* Biological control methods need to be developed for areas that have been invaded.

Wetland animals require large areas of adjacent uplands as high tide refuges. *Evidence:* When the tide is high, or when storm waters raise sea level, wetland animals, many of which have terrestrial affinities, have no safe retreat. During storm peri-

ods, endangered rails have been observed in urban uplands, where they risk predation from pets and raptors and injury from automobiles. *Research needs:* The requirements of wetland animals for adjacent uplands need to be quantified, with observational data in times of extreme high water, and with comparisons in urban wetlands and rural coastal wetlands (e.g., in Baja California). *Management needs:* Buffers need to be designed based on quantitative information.

Insect-pollinated plants require adjacent uplands to support their pollinators. *Evidence:* The endangered salt marsh bird's beak (Cordylanthins maritimus ssp. maritimus) was transplanted to a small island within Sweetwater Marsh NWR, where the nearby uplands are urbanized. The plants grew and flowered, but seeds were rare, due to lack of pollination. The native pollinators are small bees that nest in higher-elevation habitat, which was lacking on the island. *Research needs:* We need to determine the habitat requirements of critical pollinator species. If their habitat is limiting, we need new techniques to provide artificial habitats adjacent to wetland restoration sites. *Management needs:* Better designs are needed for wetland restoration projects, with appropriate linkages between wetlands and uplands.

Herbivorous insect populations will continue to cause problems in manmade salt marshes. *Evidence:* The cordgrass of San Diego Bay's dredge spoil island experienced considerable herbivore damage from a native scale insect (Haliaspis spartina) outbreak. The population apparently built up over a four-year period, during which the native predatory beetle (Coleomegilla fuscilabris) failed to establish and control the scale insects. Much of the cordgrass is now sparse and short, thereby decreasing chances that beetles can control the scale, as the beetle needs tall vegetation to use as a high-tide refuge. *Research needs:* We need to determine the requirements for establishing and sustaining populations of native predatory insects. If short cordgrass is the limiting factor, we need to determine what soil amendments would produce tall plants at this site. *Management needs:* In the short term, it appears necessary to provide artificial habitats for beetles. Beetles will need to be reared, introduced, and monitored, and cordgrass cover and height will need to be evaluated over several years to predict and respond to further problems.

The disturbances of construction and development adjacent to wetlands are detrimental to native birds. *Evidence:* Construction activities have been underway for 7 years at the Sweetwater Marsh National Wildlife Refuge. The endangered Light footed Clapper Rail disappeared from Paradise Creek marsh when freeway widening began. Whether or not it can return is uncertain. Population size is declining throughout the Refuge, and the population may be too small to recover once construction activities are terminated. A major new development, including several high-rise buildings, has been proposed for the adjacent uplands. *Research needs:* The impacts of nearby noise, lights, movement, traffic, predatory pets, and flight-path obstructions need to be quantified. *Management needs:* Appropriate designs for buffers are needed; ordinances to control activities within buffers are needed.

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Prepared Statement of Dr. Russ Lea

BACKGROUND

Existing landscapes can often be modified to increase or enhance particular wetland functions and degraded wetlands can also be modified to restore natural functions. For example, the U.S. Fish and Wildlife Service has used dikes, dams and other techniques to increase and manipulate water levels for many years for the purpose of enhancing the waterfowl habitat value of a pre-existing wetland. Often this has involved active management such as deepening portions of the wetland, control of exotic species, and in some cases, increase specific wetland functions. in another example, vast areas of wetlands have been modified for intensive use for agricultural or silvicultural production. However, modification of natural wetlands to increase particular functions may mean that other functions are decreased such that the cumulative impacts are significant to the sustainability of the system, or the downstream influences deemed unacceptable.

Experimentally, one refers to the above paradox as cumulative impacts assessment. Scientifically, cumulative impacts represent complex research challenges with exciting conceptual approaches to model the many aspects of wetland function and structure. Their study requires field sites where research design dictates land use control, and they require long-term studies involving multiple expertise. Cumulative im-pacts also refers to the consequences and measurement of the effects of perturbations in an integrated fashion on both natural and restored, created or altered ecosystems.

From a scientific perspective, much is still unknown about how natural wetlands function, let alone those that have been significantly modified. Even less is known about how to restore or create certain wetland functions, and how resilient these functions are to chance events or long-term environment degradation. Currently, almost no cause and effects relationships have been established between hydrology and soils with respect to sustainability of restoration, creation or modification projects, or to provide indices of parameters that are useful for monitoring persistence.

Scientists agree that without adequate long-term-term hydrologic and soil hydraulic design, wetland restoration or creation is not possible or projects will ultimately fail. Wetlands must continue to wet at proper depths, for proper lengths of times, with adequate nutrient fluxes and water quality, and with periodic cycles, such as flooding, synchronous with the natural requirements of the plant communities. Given that it is our goal to provide wetland systems that are self-sustaining, is there opportunity to improve (enhance) the functions of naturally occurring or degraded wetland systems?

APPROACH

Most forest wetland restoration/creation projects in the Southeast have been established with little or no attention toward obtaining stated goals based on functions. Because of the lack of specified goals it has been difficult for agency scientists to evaluate "success". Furthermore, given the long-term proposition of re-establishing wetland forests, monitoring success has to be linked with an understanding of the functional replacement of natural systems. Because forested mitigation project sites encompass a wide range of conditions, scientists from industry, universities and agencies came together, using US EPA Region IV Leadership, to develop a forested wetland mitigation classification system. The classification system, MiST (Mitigation Site Type Classification), is based upon the premise that the success of a

forested mitigation project is dependent on the initial condition of the mitigation site. Once the condition of the soil, hydrology and vegetation has been assessed, then the degree to which the site has the potential of returning to a high functional state can be established. The "scale" of the project is then established relative to an adjacent "undisturbed" reference ecosystem, and the degree of success (using soils, vegetation and hydrology) is based on the overlap in functions between the mitigation and reference sites.

Regardless of the refinements made to the system following field testing, a major strength of MiST is that it provides an avenue for communication between regulators and mitigators by establishing a standard approach for evaluation of mitigation plans. And, important to restoration ecologists, it provides a framework for illuminating the most pressing needs for restoration research relating to forested wetland ecosystems.

While MiST addresses concerns related specifically to Section 404 of the CWA, an additional benefit of MiST is the potential for its use outside of CWA regulatory programs. Classification of mitigation sites and development of performance criteria and monitored characteristics can lead to better restoration of lands such as those currently under consideration for conversion to wetland forest ecosystems through programs initiated in the Conservation Reserve Program and the Swampbuster provision of the Food Security Act of 1985 (Farm Bill). Thus, use of MiST may not only assist in mitigation of wetland disturbances but may also contribute to increasing the quality and quantity of the Nation's wetland resource.

NEEDS

There is a strong need for technical training and education for a broad range of groups to underpin implementation of the no net loss goal. We are legion in our appeal for training State agency personnel, local governments, Federal agency personnel, consultants and landowners with regard to standards and techniques for implementing the no net loss goal, evaluating the functions of wetland, wetland delineation, and wetland restoration and creation (including the evaluation of projects).

> "The United States cannot attain a goal of no net wetlands losses, much less the goal of increasing the wetlands base, without initiating active programs of wetlands restoration and creation.
>
> "Wetlands restoration involves either improving the condition of existing degraded wetlands so that the functions they provide are of a higher quality or reestablishing wetlands where they formerly existed before they were drained or otherwise converted. Wetlands creation is much more uncertain because it involves creating new wetlands where they do not now exist and have not existed in recent times." —*National Wetlands Policy Forum, November 1988.*

The above statement, while provocative, represents the opinions of the regulatory agencies in the implementation of the "no net loss" doctrine which was recently handed down by consensus in the Wetlands Policy Forum. interestingly, however, the interpretation of this doctrine will be openly left up to local arbitration and experience.

Regulatory agencies are in desperate need of a general philosophy to guide their actions in the area of wetland mitigation, but cannot do so because of scientific uncertainty.

Construction and scientific monitoring of mitigation sites can assist the basic research needs of regulatory agencies and if scientifically proven to be successful, mitigation efforts can indeed be a valuable tool in carrying out the Clean Water Act's "mandate to restore and maintain the chemical, physical and biological integrity of the Nation's waters."

Mitigation efforts, in general, may effectively restore some of the Nation's wetlands and even perhaps create healthy, functioning new wetlands.

Hundreds and perhaps thousands of coastal and estuarine mitigation projects have been constructed along the eastern seaboard. These projects have bene subject to a fair amount of follow-up monitoring and have been widely reported in literature. in contrast, much less is known of the amount of inland bottomland hardwood restoration and creation projects where success is less certain and the timetable for success more variable.

The challenge for all applicants is to continually add to the science of wetland creation and restoration so that the agencies can develop reasonable analytical frameworks by which to pass performance hurdles. Experience to date indicates

that too little is known about restoration and creation, and there are too many variables to predict success for restoration or creation in may contexts.

PRIVATE INDUSTRY/UNIVERSITIES CAN TAKE LEAD IN RESTORATION AND CREATION

The expenditure by private industry for work on private property to mitigate adverse impacts for the overall public good may be difficult to accept for agencies that have brokered public interest in wetlands. North Carolina's approach is to take this substantial investment of private funds as an academic opportunity in leveraging public support and open-minded approaches to mitigation based upon ecological, design and engineering principles.

The incentives are already being realized by the mining industry in the Southeast. Operators there are establishing projects using the on-site expertise of local university staff working in conjunction with interested regulatory agencies. The university is currently developing the conceptual framework to assess restoration and creation standards by a consensus of agencies, industries, universities and consultants. in the mining industry, in particular, where economic, environmental and engineering problems transcend the jurisdictional boundaries of several States, there is opportunity to organize a consortium of industries and agencies to orchestrate research that is both innovative and applied. Using university resources, research needs can be generically delineated, and prohibitions to create improved experimental efforts relaxed.

One of the most exiting results to come from our recent collaborations with industry and agencies is a recognition that multidisciplinary teams can work effectively to assemble human-scale environments for research, planning and design purposes (see attached reprint). Scientific visualization techniques using computer aided design, can produce real-world phenomena and spatial characteristics which have been displayed in ways to "walk" the viewer through a virtual wetland creation.

While creating wetlands is not new, North Carolina State University is proposing to examine generic ways of reducing the risks while enhancing the public interest and allowing all interested parties the experience of "earthscraping" in a virtual sense prior to construction.

While science may be nascent to describe exactly what constitutes a successfully mitigated wetland acre, there is an effort being made to bring the teams together in an academic setting to train the multitude of future mitigators so desperately needed.

BEVERIDGE & DIAMOND, P.C.
WASHINGTON, DC. 20005
April 30, 1991

Hon. MAX BAUCUS
Hon. DAVE DURENBERGER
United States Senate
Subcommittee on Environmental Protection, Environment and Public Works Committee, Washington, DC.

Dear SENATORS BAUCUS, DURENBERGER AND MEMBERS OF THE SUBCOMMITTEE:

The Foundation for Environmental and Economic Progress submits the following for inclusion in the record of the Subcommittee's April 9, 1991 hearing on the status of wetlands science. The Foundation is an association of large landowners and community developers which build schools, homes, shopping centers, low-income housing, sports facilities, industrial parks, and many other projects. Its members have had experience with wetlands creation, enhancement and restoration throughout the United States.

The Foundation believes that the restoration, creation and enhancement of wetlands is possible. Some wetlands are easier to restore, create or enhance than others. Nevertheless, the literature is filled with examples of successful projects in many areas of the country involving many wetlands types. In particular, a recent EPA publication entitled *Wetland Creation and Restoration: The Status of the Science* (U.S. Environmental Protection Agency, October 1989) is replete with examples of successful restoration, creation and enhancement. We have enclosed excerpts from this and several other publications for inclusion in the hearing record to ensure that the record demonstrates that wetlands restoration, creation and enhancement can be and has been accomplished.

There have, of course, been some failures. However, this is to be expected with any new science. The enclosed materials indicate that, as more experience is gained,

greater success is achieved. Moreover, some project failures can be attributed to failure to implement plans properly or lack of monitoring. Such problems can be addressed through appropriate permit conditions. The Foundation believes it would be wrong to set wetlands policy on the erroneous premise that compensatory mitigation for wetlands impacts is not feasible.

If you have any questions regarding this material or other aspects of wetlands science and policy, please feel free to contact us at the number above or Mr. Bob Wilhelm, The Foundation President, at 407-479-1170. Thank you for extending the comment deadline and for your concern and interest in the issue of wetlands science.

Sincerely,

THOMAS C. JACKSON

DOCUMENTS SUBMITTED FOR THE RECORD BY THE FOUNDATION FOR ENVIRONMENTAL AND ECONOMIC PROGRESS ON THE STATUS OF WETLANDS SCIENCE

1. Association of State Wetland Managers, Inc., *Mitigation of Impacts and Losses, Proceedings: National Wetland Symposium,* New Orleans, Louisiana, October 8-10, 1986.

Excerpts:
"Hydrologic Manipulation and Restoring Wetland Values: Pine Creek, Fairfield, Connecticut."
"Wetland Development and Restoration as Part of Corps of Engineer Programs: Case Studies."

2. Association of Wetland Managers, Inc., *Urban Wetlands, Proceedings of the National Wetland Symposium,* Oakland, California, June 26-29, 1988.

Excerpts:
"A Review of Eighteen Wetland Mitigation Sites in the San Francisco Bay Region"
"Warm Springs Marsh Restoration."

3. Jon A. Kusler and Mary E. Kentula, Eds., *Wetland Creation and Restoration: The Status of the Science, Vol. I: Regional Reviews,* Environmental Protection Agency (600/3-89/038n), October, 1989.

Excerpts:
"Creation and Restoration of Coastal Wetlands in Puerto Rico and the U.S. Virgin Islands."
"Creation and Restoration of Forested Wetland Vegetation in the Southeastern United States."
"Freshwater Marsh Creation and Restoration in the Southeast, Appendix I: Project Profiles."
"Regional Analysis of Fringe Wetlands in the Midwest: Creation and Restoration, Appendix II: Project Descriptions."
"Riparian Wetland Creation and Restoration in the Far West:A Compilation of Information, Appendix VI: Project Profiles."

4. David Salvesen, *Wetlands: Mitigating and Regulating Development Impacts,* ULI-the Urban Land Institute, 1990.

Excerpts:
"Bayport Plaza, Tampa, Florida."
"Brookshire Estates, King County, Washington."
"Creating a Salt Marsh in Long Island, New York."
"Westford Corporate Center, Westford, Massachusetts."

(The documents listed above have been received and are being retained in committee files.)

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